TREASURY DEPARTMENT
Public Health and Marine-Hospital Service of the United States

HYGIENIC LABORATORY.—BULLETIN No. 72
NOVEMBER, 1910

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BY

L. L. LUMSDEN

II. THE WATER SUPPLY OF WILLIAMSON, W. VA., AND ITS RELATION TO AN EPIDEMIC OF TYPHOID FEVER

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United States Public Health and Marine-Hospital Service.

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I. REPORT ON AN OUTBREAK OF TYPHOID FEVER AT OMAHA, NEBR. (1909–1910).[a]

By L. L. Lumsden,

Passed Assistant Surgeon, United States Public Health and Marine-Hospital Service, Hygienic Laboratory, Washington, D. C.

INTRODUCTION.

The city of Omaha, Nebr., is situated on a series of hills rising gradually from the west bank of the Missouri River. For the greater part of the city the general slope of the land is toward the river, and thus excellent natural drainage is afforded.

The city's present population is estimated at about 138,000, and for the last ten years has varied probably between that number and 100,000. The water supply has been obtained, for the most part, for certainly the last twenty years, from the Missouri River. This river, at numerous points north of Omaha, receives the sewage from a large number of persons, and therefore can be regarded as a somewhat dangerously polluted stream. The treatment of the water before being distributed to the city has not been such as to render it reasonably free from dangerous pollution. Notwithstanding the character of the water supply, Omaha did not have during the twenty years prior to 1909 a typhoid fever rate which could be considered much, if any, above the average for other American cities having comparable climatic and sanitary conditions.

In the latter part of November, 1909, the rate of prevalence of typhoid fever in Omaha became unusually high, and continued so until the latter part of March, 1910. From December 1, 1909, to April 1, 1910, there were reported 582 cases with 59 deaths. The death rate from typhoid during this period was over six times as high as the average rate for the corresponding periods of the five years previous, and, as far as the records show, much higher than it ever had been in this period of any previous years.

Gradually the people awakened to the fact that their city was being visited by an outbreak, or epidemic, of typhoid fever. This

[a] Manuscript submitted for publication June 21, 1910.

awakening was brought about largely by discussions of the subject in the local medical society and by publications in the local newspapers.

Suspicion fell upon the water supply as the source of the infection, and the city commissioner of health advised the people to boil the water before using it for drinking or culinary purposes. There were among the local physicians and the people generally, however, at the time this investigation was begun, many conflicting views expressed as to the cause of the outbreak, and even among those who stated as their belief that the water supply was at fault there were marked differences of opinion as to the source of the infection in the water.

Finally, the Omaha-Douglas County Medical Society sent a petition to the governor of the State requesting that he use his influence to secure a thorough investigation of the situation by an officer of the United States Public Health and Marine-Hospital Service. This petition was signed by the mayor and the commissioner of health of Omaha. Upon the receipt of this petition the governor sent the following letter to the Secretary of the Treasury:

STATE OF NEBRASKA, EXECUTIVE OFFICE,
March 4, 1910.

DEAR MR. SECRETARY: The water supply of the city of Omaha, in the opinion of the health department of that city, has become more or less contaminated with typhoid-fever germs and considerable sickness has resulted therefrom, and at the direction of the mayor of the city and the city physician and other members of the board of health, I am requested to ask you, if possible, to designate a competent officer from the Marine Hospital Corps to go to Omaha and report to Dr. Ralph W. Connell, the city physician, with instructions to make investigations as to the contamination of the water supply and to advise proper means for remedy of existing conditions and prevention of further spread of the disease. What is wanted is an officer who is an expert upon the subject of water supply and purification and a bacteriologist as well.

Trusting that it may be found compatible with the good of the public service to help the city officials of Omaha in this way, I subscribe myself with profound respect,

Yours sincerely,

ASHTON C. SHALLENBERGER.

HON. FRANKLIN MACVEAGH,
Secretary of the Treasury, Washington, D. C.

The Secretary referred the matter to the Surgeon-General of the United States Public Health and Marine-Hospital Service, and with the approval of the Secretary of the Treasury, the Surgeon-General detailed the undersigned to proceed to Omaha "for a conference with the commissioner of health of that city and investigations of the origin and prevalence of typhoid fever, especially in relation to water supplies."

The investigation of the Omaha situation was begun on March 28 and completed on April 23. The investigation included a sanitary survey of the Missouri River watershed from Omaha to points about 10 miles north of the first intake for the city's water supply; bacteriologic examinations of the water supply; an epidemiologic study

of 105 individual cases of typhoid fever reported between March 1 and April 15 and taken to be fairly representative of all the cases occurring in the outbreak; a clinical examination of about 50 cases reported as typhoid; the making of blood cultures and Widal tests in a number of cases to aid in the determination of the clinical diagnoses; an inspection of the principal dairies; a study of the health-office records; an inquiry into the prevalence of typhoid in neighboring towns and cities; and a careful consideration of the city's sewerage system, and of the supplies of foods and beverages generally.

Upon the completion of the investigation, on April 23, a preliminary report, with conclusions and recommendations which appeared most pertinent to the immediate situation, was submitted to the commissioner of health of Omaha.

In the following report the data collected during the course of the investigation, together with conclusions and recommendations based thereon, are given in detail.

In compliance with instructions received from the Surgeon-General this investigation of typhoid fever in Omaha was made in cooperation with the commissioner of health of that city. Appreciation is hereby expressed of the hearty cooperation of Dr. Ralph W. Connell, commissioner of health of Omaha, and his assistants. From the records of the health office, Doctor Connell furnished numerous transcripts and special compilations. Mr. Claude F. Bossie, one of the sanitary inspectors connected with the health office, was detailed to assist in the investigation, and in every way rendered excellent service.

The bacteriological work was done in the laboratory of the Creighton Medical College, from the authorities of which institution many courtesies were received. In the making of Widal tests, in the preparation of media, etc., at the laboratory, material assistance was received from the city bacteriologist, Dr. Millard Langfeld.

Mr. George W. Craig, the city engineer, and his assistants, rendered valuable assistance in the work. Mr. Craig furnished from his office much important detailed information, including maps and charts, in regard to the city's water supply and sewerage system, and, besides, either went in person or sent an assistant on the surveys of the Missouri River watershed and of the city's water and sewerage systems and in the sanitary inspections of a number of neighboring towns and villages.

Valuable service was rendered by the local newspapers in keeping the public informed as to the nature and results of the investigation.

From the members of the medical profession of Omaha many courtesies and much valuable assistance were received. It was at the instigation of the Omaha-Douglas County Medical Society that this investigation was brought about.

NATURE AND SCOPE OF THE INVESTIGATION.

The immediate purpose of the investigation was to determine the cause of the unusually high rate of prevalence of typhoid, which had begun in the latter part of November, 1909, so that preventive measures might be adopted. The time of occurrence and the character of the outbreak pointed to the water supply, the milk supply, or some other general food supply as the chief source of the infection, and therefore especial attention was given at the beginning of the investigation to these supplies.

A rapid and somewhat superficial survey of the river near by the two points from which the city's water supply was obtained showed that there was dangerous local pollution of the river with sewage. This observation was made within the first two or three days of the investigation, and a statement was then given to the local newspapers and made before the local medical society that, in view of the conditions already discovered and pending the results of a complete investigation of the situation, it was highly advisable for the people to boil the river water before using it for drinking or culinary purposes. A detailed survey of the watershed of the river for some miles above Omaha and a bacteriologic study of the water supply were made as expeditiously as possible, and the results were all confirmatory of the first impression that the water as supplied to the city was dangerously polluted with sewage. Thus the water supply was involved as a possible chief factor in the production of the outbreak. The investigation was made to include a study of all other possible factors which could reasonably be considered to have been operative, in order to determine which of these factors could be involved and which eliminated. To ascertain the conditions liable to be concerned in the production of typhoid fever, to which the persons affected had been exposed prior to illness, an epidemiologic study was made of 105 individual cases. This study comprised a visit to the home of the patient, a sanitary inspection of the premises, and a careful inquiry to collect from the patient or from other members of the household all data called for by the following blank form:

TYPHOID FEVER CASE CARD.

Case No.....
Date reported.....
Date of investigation.....
Name.....Resident in Omaha: years.....; months.....
Age.....Color.....Sex.....Nationality.....
Probable date of onset.....Date of definite symptoms.....
Name and address of physician.....

Residence:

Character of.....
Residence when taken sick.....from.....to.....
Previous residences.....from.....to.....
Subsequent residences.....from.....to.....
Temporary absences from Omaha within thirty days prior.....
Number of occupants.....Ages.....
Number of occupants who have had typhoid fever.....when.....
Newcomers in house within three months prior.....
Newcomers had typhoid?.....
Servants:
White: Resident.....
Name.....
Address.....
Typhoid .....
Nonresident.....
Name.....
Address.....
Typhoid.....
Colored: Resident.....
Name.....
Address.....
Typhoid.....
Nonresident.....
Name.....
Address.....
Typhoid.....
Typhoid at home of servants.....when.....
W. C. in house.....W. C. in yard.....
Privy.....location.....
General sanitary condition of residence.....
House screened?.....Flies?..... ...Other insects?.....

Occupation:

Place.....from.....to.....
Drinking water.....
Other cases.....

Water within thirty days prior:

Solely.....Principally.....Occasionally.....
Source of ice used in or for drinking water.....

Food within thirty days prior:

Where taken.....
Milk (how used).....From.....
Boiled?.....Pasteurized?.....
Ice cream.....Where?.....
Uncooked fruits and vegetables.....Lettuce.....Onions.....
Celery.....Radishes.....Strawberries.....
Raw shellfish.....

Contact:

Association thirty days prior with patients in febrile stage.....
Association with suspected cases?.....
Association with persons who have had typhoid within—
Six months.....
One year.....
Two years.....
Three years.....
Four years.....
Five years.....
Association thirty days prior with persons in contact with patients in febrile stage.....
Treatment of stools and urine of patient.....
Other precautions.....
Remarks .....
Summary.....

Signature .....

The 105 cases so canvassed were reported from March 15 to April 15, and had definite onsets of illness between January 14 and April 9. They were taken serially in the order in which they were reported to the health office and are believed to be fairly representative of all the cases which occurred in the outbreak.

OCCURRENCE AND EXTENT OF THE OUTBREAK.

Judging by the rate of report of cases to the health office, the outbreak of typhoid fever at Omaha began about November 25, 1909, and continued until about March 25, 1910. From December 1, 1909, to April 1, 1910, 582 cases were reported. The following table shows the number of cases and deaths reported, by days, from December 1, 1909, to June 1, 1910:

TABLE NO. 1.—*Giving typhoid fever cases and deaths reported, by days, in Omaha.*

Day of month.	1909.		1910.									
	December.		January.		February.		March.		April.		May.	
	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.
1					1		8	2	14			
2		2	4		7		8	1		1		
3	5		2		5		3	1			3	
4	2	1			7		9		4	2	2	
5			2	1	29		2	2	1	1		
6	2		2	1		1		2	1	1		
7	2				7	1	9	2	3			
8	3			1	8	1	8	2	4			
9	10				10		9	2			1	
10	20		1		21		10			1		1
11			1		17		4		2			
12					11	2	2	1	2		1	
13	5	1				1			1		1	
14	8	1	2		20		9		1			
15	3		1		10		3			1		
16	6	1			12	1	6			2		
17	1		4		4	2	4	3				
18	5		2		8	1	4	1			1	
19		1	1		11		1				1	
20	4		2	1				1	1			
21	10	1	5		4	1	6	1			1	
22	1		2		6		6					
23					13	1	4			1	1	
24	8	1	6		11	1	1				2	
25			3		11	1	7	1	3			
26			4		7	2	5				1	
27	2		8					2			1	
28	4		9		6		7	1	2			
29			2				10	1	1			
30	3						3	1	5			
31	10	2	5				6	2			2	
	114	11	68	4	246	16	154	28	45	10	18	1

The records show that the report of cases previous to the latter half of 1909 was very incomplete. Therefore it is impossible to use the report of cases as a basis for a comparison of the rate of prevalence during the period of the outbreak with the rates for corresponding periods of previous years. The report of deaths, however, appears to have been quite complete for some years past, and may be used as a fair basis for comparison.

From December 1, 1909, to April 1, 1910, the number of deaths from typhoid fever reported was 59. For the four corresponding periods of the years immediately preceding those in which the outbreak occurred the numbers were as follows:

Number of deaths from typhoid fever reported:

December 1, 1905, to April 1, 1906	8
December 1, 1906, to April 1, 1907	8
December 1, 1907, to April 1, 1908	9
December 1, 1908, to April 1, 1909	12

The average for these four periods is nine, which is less than one-sixth the number reported in the period extending from December 1, 1909, to April 1, 1910.

Table No. 2 and Chart No. 1 show the number of deaths from typhoid fever reported, by months, during the calendar years from 1905 to 1910.

TABLE NO. 2.—*Showing number of deaths from typhoid fever reported, by months, in Omaha.*

Month.	1905.	1906.	1907.	1908.	1909.	1910.
January	1	2	3	1	1	4
February	2	3	.....	2	1	16
March	4	2	1	2	1	28
April	1	.....	4	.....	4	10
May	.....	2	1	.....	.....	1
June	3	3	1	1	3	.....
July	1	1	1	1	2	.....
August	1	.....	1	2	3	.....
September	3	2	2	5	6	.....
October	2	5	4	1	3	.....
November	2	4	3	2	2	.....
December	1	4	4	9	11	.....
Total	21	28	25	26	37	.....

Chart No. 2 shows the aggregate number of deaths from typhoid fever reported, by months, during the four years 1905 to 1908, inclusive. Judging by these charts (Nos. 1 and 2) it appears that the

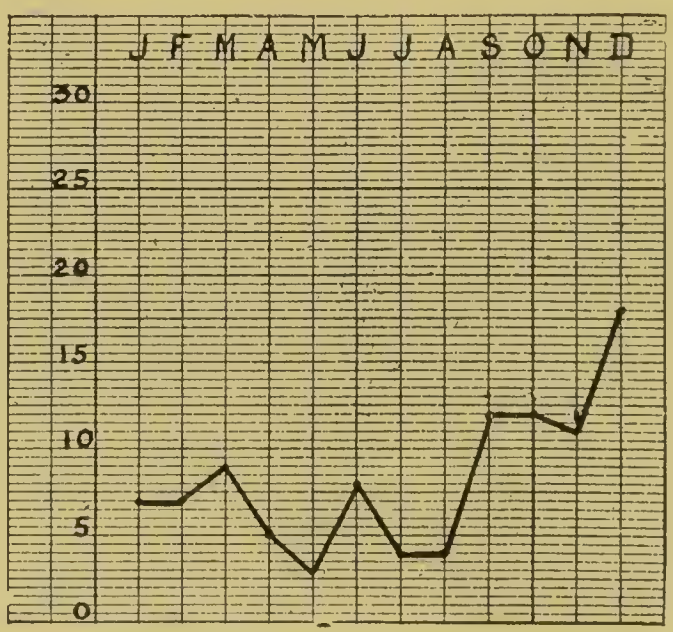


CHART NO. 2.—Showing the number of deaths from typhoid fever reported in Omaha during the four years 1905 to 1908, inclusive, in monthly aggregates.

prevalence of typhoid fever (by occurrence of cases) in Omaha usually is greatest during the summer and fall, and, therefore, that the factors in the production of typhoid fever there usually are operative

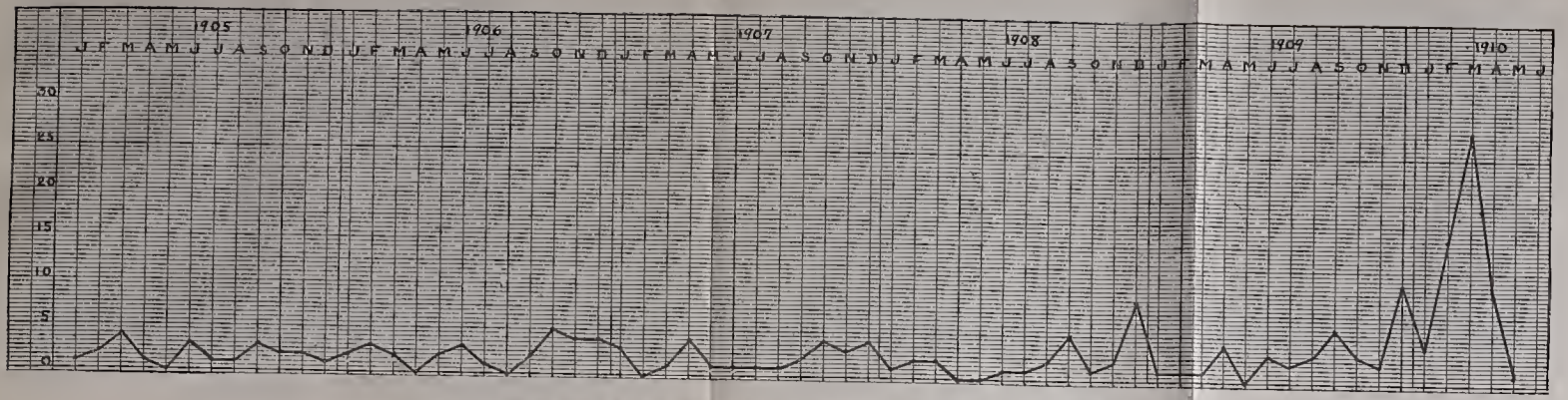


CHART No. 1.—Showing number of deaths reported from typhoid fever in Omaha, from January 1, 1905, to June 1, 1910.

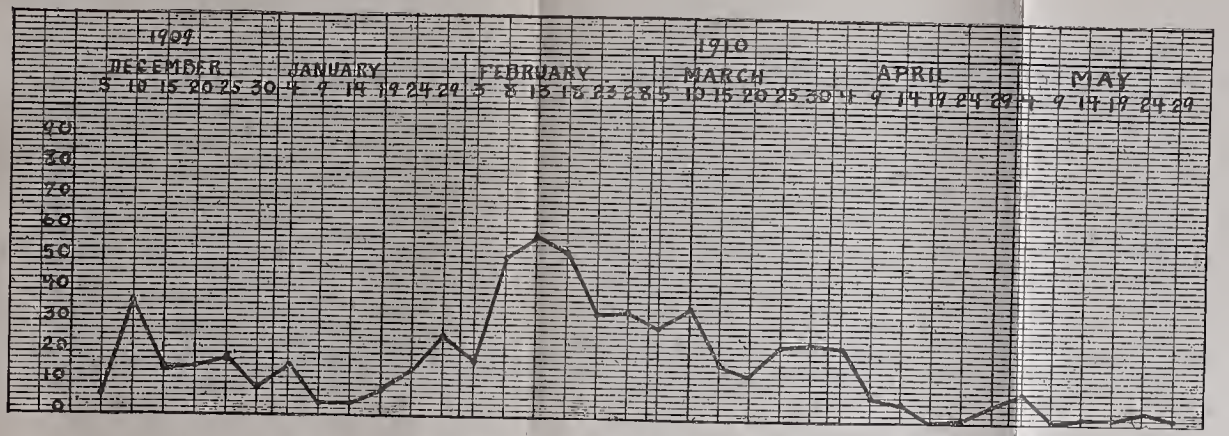


CHART No. 4.—Showing number of cases of typhoid fever reported in Omaha from December 1, 1909, to June 1, 1910, in five-day periods.

to the greatest extent during the months of July, August, September, and October.

The time of occurrence of the outbreak of 1909–10, as is shown in charts Nos. 1, 3, and 4, therefore, was not the seasonal period in which typhoid in Omaha usually is most prevalent. Judging by the rate of report of cases the outbreak had its causation in conditions

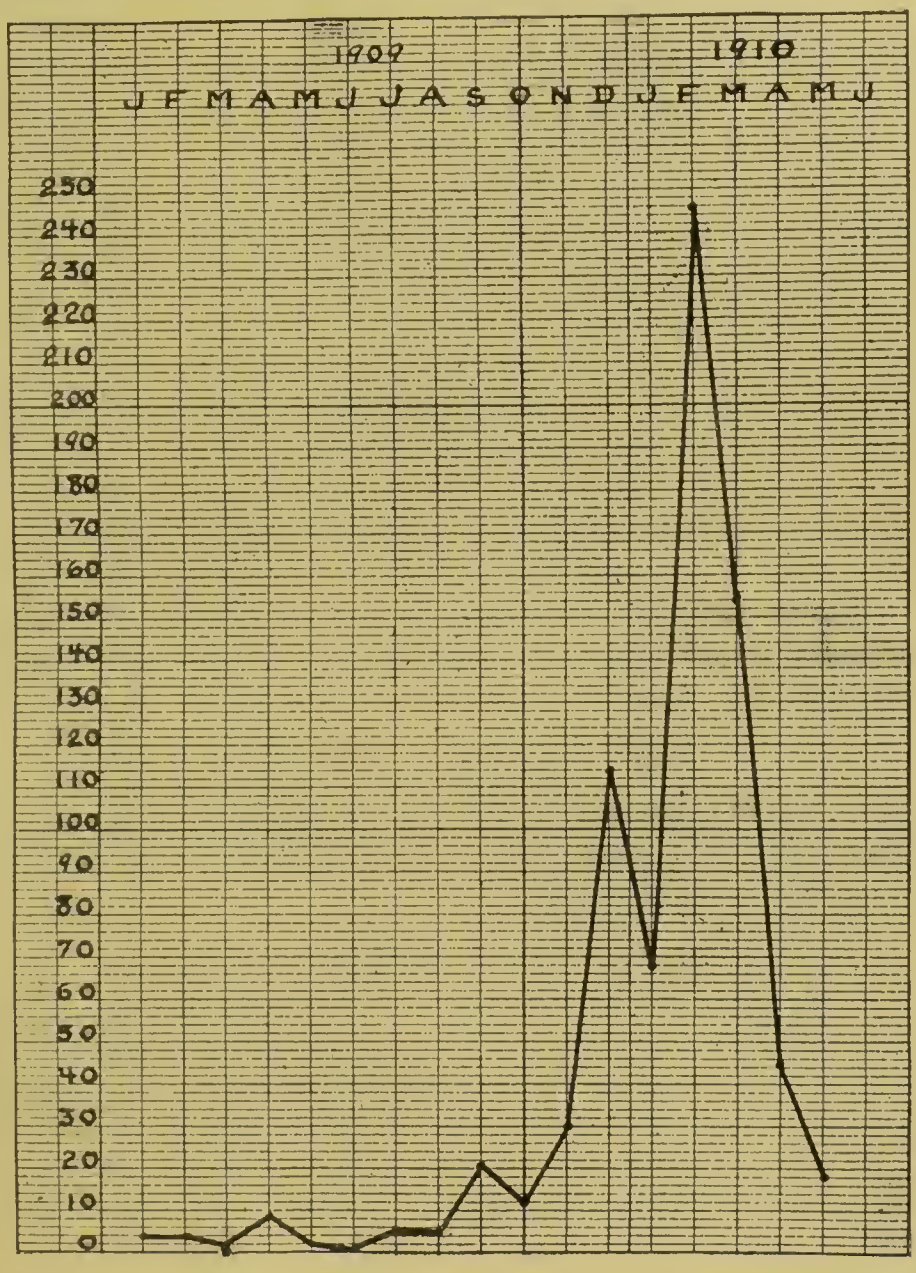


CHART No. 3.—Showing typhoid cases, as reported by months, in Omaha before and during the period of the outbreak.

which became operative about November 15, 1909, diminished somewhat in December and the early part of January, then markedly increased to reach the maximum about January 25, from which time they continued operative at a diminishing but still high rate until about March 15, 1910, when they rapidly declined. (See Chart No. 4.)

Some idea of the extent of the outbreak may be obtained by a consideration of the following table, showing the number of deaths

from typhoid fever in Omaha for the fifteen calendar years preceding those of the outbreak:

TABLE No. 3.—*Giving the number of deaths from typhoid fever in Omaha for the calendar years 1895 to 1909 and for the first three months of 1910.*

Year.	Number of deaths reported from typhoid fever, according to records of health office.	Population of Omaha according to United States census reports or estimates.	Year.	Number of deaths reported from typhoid fever, according to records of health office.	Population of Omaha according to United States census reports or estimates.
1895	29	(a)	1904	19	.....
1896	19	.....	1905	21	120,565
1897	25	.....	1906	28	.....
1898	32	.....	1907	25	.....
1899	26	.....	1908	26	.....
1900	24	102,555	1909	37	.....
1901	23	.....	January, February, and March, 1910	48	138,574
1902	21	.....			
1903	11	.....			

a Official estimate of population in 1895 is not obtainable, but the actual population then was probably about 95,000.

It is evident that the number of deaths (48) in the first quarter of 1910 exceeded considerably the number recorded in the whole of any one of the previous years.

AGES OF PERSONS AFFECTED.

As far as could be ascertained from the report of cases recorded at the health office, the ages of the persons affected during the period of the outbreak were as follows:

TABLE No. 4.—*Giving ages of persons affected.*

	Number of cases reported.				
	December, 1909.	January, 1910.	February, 1910.	March, 1910.	Total.
0 to 4 years	8	1	7	7	23
5 to 9 years	15	7	20	21	63
10 to 14 years	8	6	32	15	61
15 to 19 years	13	10	33	23	79
20 to 24 years	15	13	46	21	95
25 to 29 years	22	2	42	19	85
30 to 34 years	11	12	18	6	47
35 to 39 years	5	3	9	5	22
40 to 44 years	2	.....	5	2	9
45 to 49 years	2	2	4	5	13
50 to 54 years	1	1	1	1	4
55 to 59 years	.....	1	3	1	5
60 to 64 years	.....	.....	1	.....	1
Not stated	12	10	25	28	75
Total	114	68	246	154	582

From Table No. 4 and Chart No. 5 it appears that the disease was distributed quite generally through the population. Persons of the age generally considered to be that of greatest susceptibility to typhoid infection—viz, from 10 to 30 years—furnished the majority of the cases.

The proportion of cases among persons under 15 years of age was not strikingly large. That there was no strikingly disproportionate incidence of the disease among children is one point in the evidence

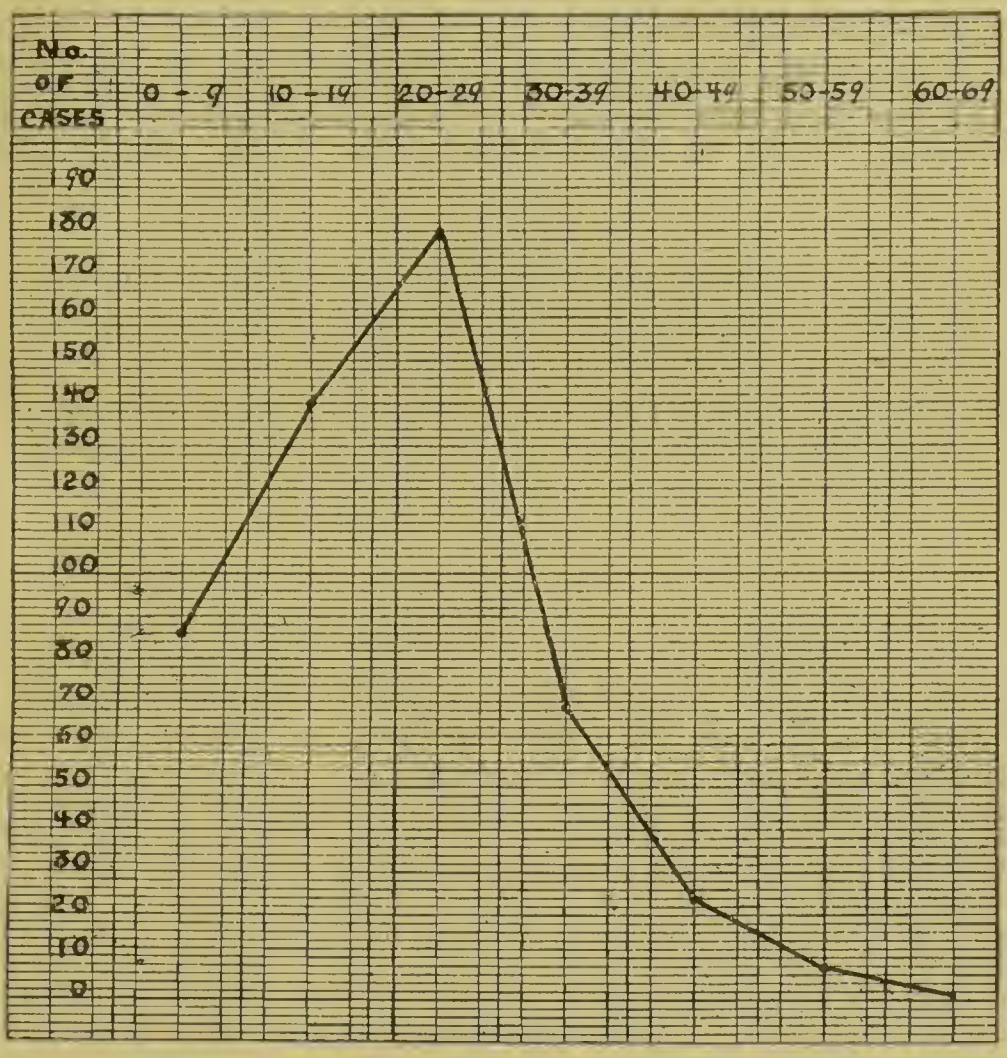


CHART NO. 5.—Showing incidence of cases among persons in different decades of life.

against the milk supply having been the chief factor in the production of the outbreak.

In this connection it is instructive to compare the proportion of cases among children in Omaha with the proportion observed to occur in Washington, D. C., where milk and contact are considered the chief factors in the spread of typhoid fever infection. In Omaha persons under 15 years of age furnished about 29 per cent of the cases occurring during the outbreak, while in Washington persons under

15 years of age furnished about 37 per cent of the cases occurring during the typhoid seasons (May 1 to Nov. 1) of 1907 [a] and 1908 [b].

GEOGRAPHICAL DISTRIBUTION.

Maps Nos. 1, 2, and 3 show the location of residences of persons affected according to addresses given in report of cases to the health office during January, February, and March, 1910.

It appears from these maps that the disease was quite generally distributed over the city. Comparatively few cases developed among persons whose residences were not in the area supplied with the city's water supply from the Missouri River. A large proportion of the persons whose residences are not connected with the city water supply no doubt use the river water either at their places of occupation or at places visited for business or social purposes.

The results of a detailed study of 105 cases indicated that the incidence of the disease was disproportionately high among persons who resided in or who had their places of occupation in an eastern section of the city bounded on the north by Lake street, on the west by Sixteenth street, and on the south by Leavenworth street. A discussion of the significance of the high prevalence among persons habitually exposed to the conditions in this section of the city is given on page 37 under the head of "Water."

DIAGNOSIS.

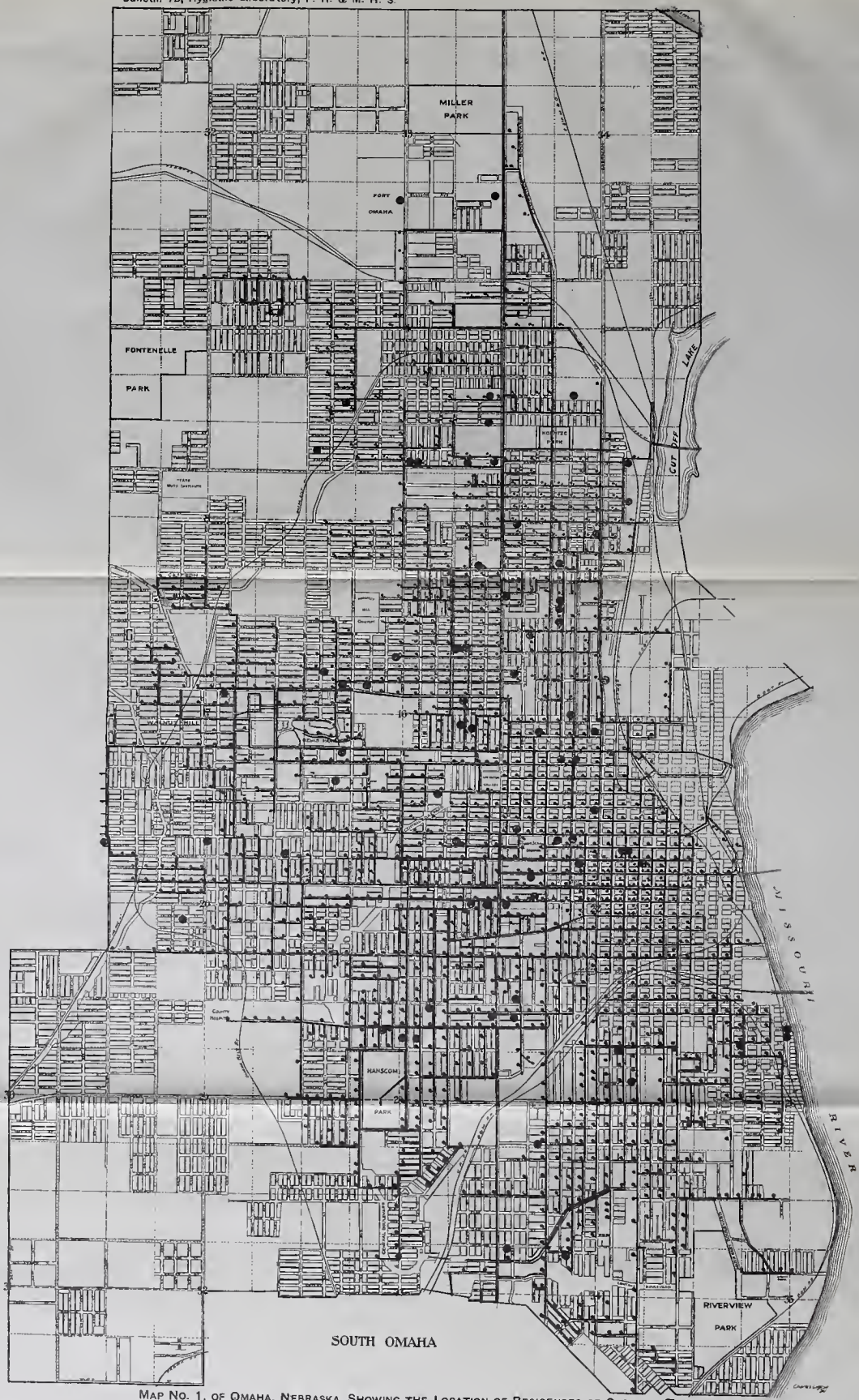
After attention has been sharply attracted to the existence of an outbreak of typhoid fever in a locality, there is always a likelihood that a number of cases will be reported by the local physicians as typhoid fever which are really cases of other diseases. At the meeting of the Omaha-Douglas County Medical Society on April 2, it was suggested by some of the physicians present that the large number of cases reported might be explained, in part at least, by erroneous diagnoses.

During the investigation a special effort was made to determine, as accurately as was then possible, the percentage of error in diagnosis. About 50 cases, still in the febrile stage of the disease, were examined clinically. The vast majority of these presented the characteristic clinical features of typhoid fever. Widal tests of the blood of about 20 patients were made and the majority gave a positive reaction. Cultures were made from the blood of seven patients and the typhoid bacillus was obtained from the blood of five. The blood serums of the two patients from whose blood the typhoid bacillus was not obtained by culture gave positive Widal reactions.

The technique followed in making the blood cultures were as follows: Five cubic centimeters of blood were taken with a syringe

[a] Hygienic Laboratory Bulletin No. 44, Report No. 2, on the "Origin and Prevalence of Typhoid Fever in the District of Columbia (1907)," pp. 15–17.

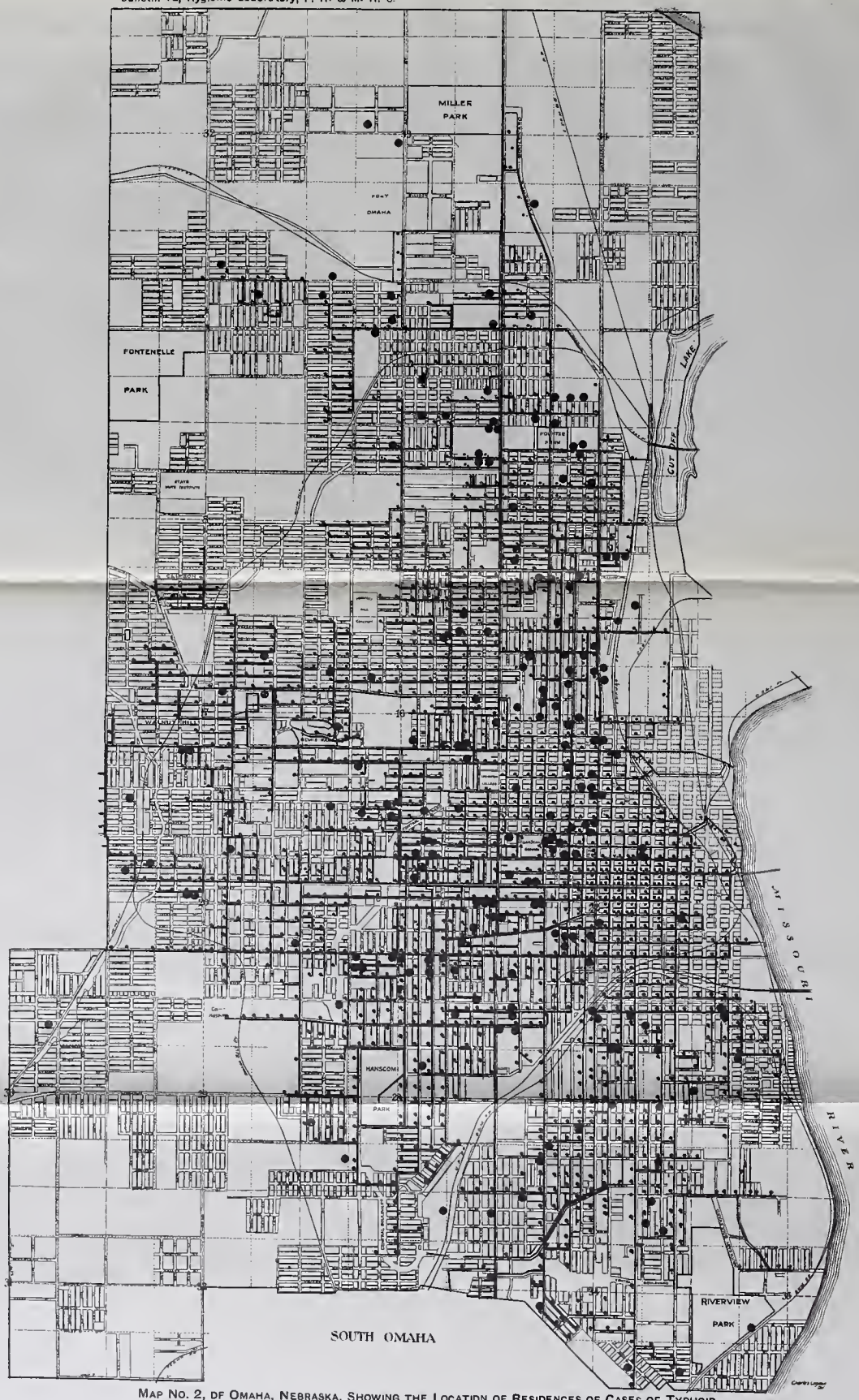
[b] Hygienic Laboratory Bulletin No. 52, Report No. 3, on the "Origin and Prevalence of Typhoid Fever in the District of Columbia (1908)," pp. 20–21.



MAP NO. 1, OF OMAHA, NEBRASKA, SHOWING THE LOCATION OF RESIDENCES OF CASES OF TYPHOID FEVER REPORTED DURING JANUARY, 1910, ACCORDING TO ADDRESSES GIVEN ON REPORT CARDS, IN RELATION TO DISTRIBUTION OF WATER-SUPPLY FROM THE MISSOURI RIVER.

● = TYPHOID FEVER CASES; TWO OR MORE DOTS WITHIN A CIRCLE INDICATE TWO OR MORE CASES IN SAME HOUSE.

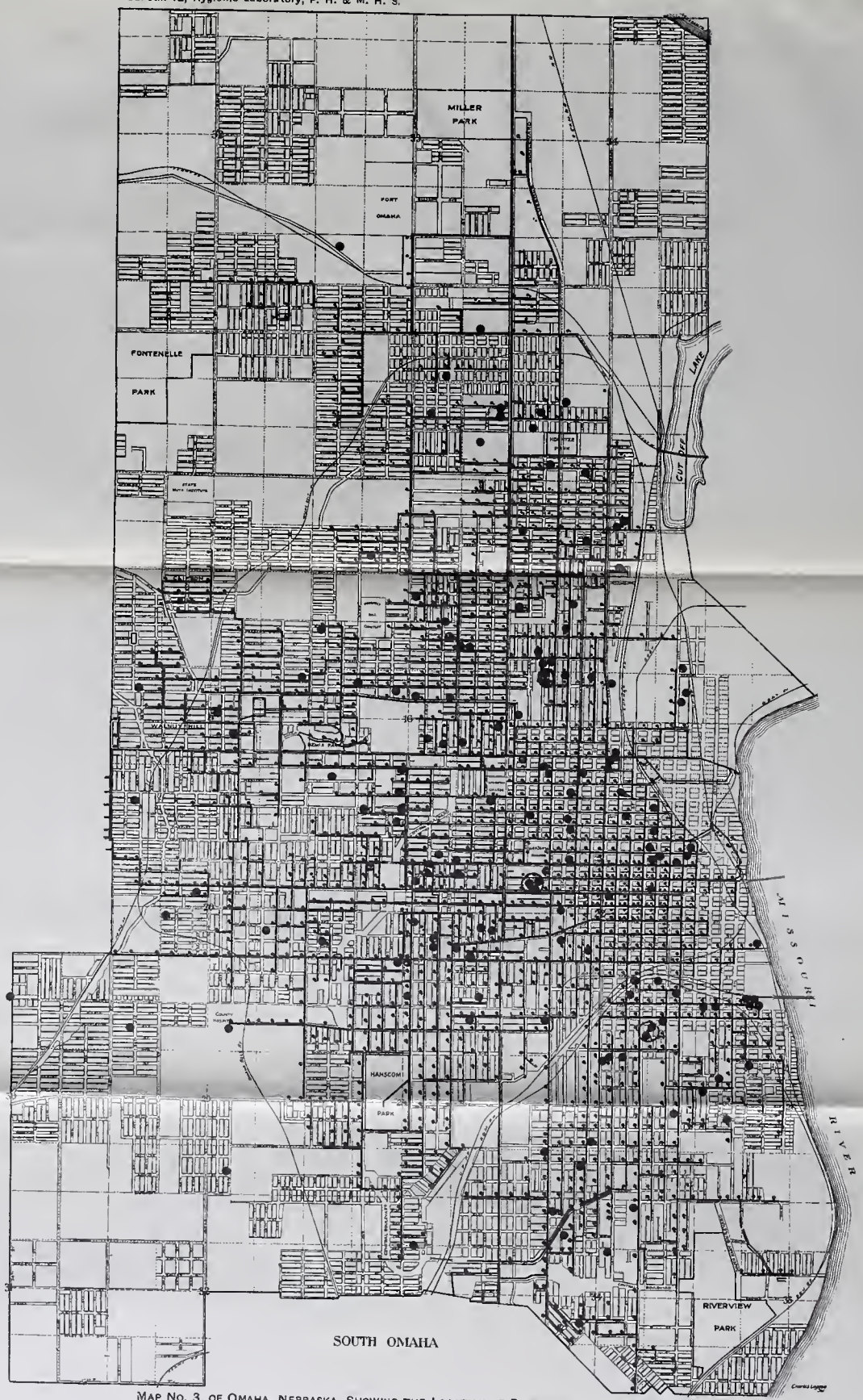
= CITY WATER SUPPLY (= PIPE LINE; = WATER HYDRANTS.)



MAP NO. 2, OF OMAHA, NEBRASKA, SHOWING THE LOCATION OF RESIDENCES OF CASES OF TYPHOID FEVER REPORTED DURING FEBRUARY, 1910, ACCORDING TO ADDRESSES GIVEN ON REPORT CARDS, AND IN RELATION TO DISTRIBUTION OF WATER-SUPPLY FROM THE MISSOURI RIVER.

● = TYPHOID FEVER CASES; TWO OR MORE DOTS WITHIN A CIRCLE INDICATE TWO OR MORE CASES IN SAME HOUSE.

= CITY WATER SUPPLY (= PIPE LINE; = WATER HYDRANTS.)



MAP NO. 3, OF OMAHA, NEBRASKA, SHOWING THE LOCATION OF RESIDENCES OF CASES OF TYPHOID FEVER REPORTED DURING MARCH, 1910, ACCORDING TO ADDRESSES GIVEN ON REPORT CARDS, IN RELATION TO DISTRIBUTION OF WATER-SUPPLY FROM THE MISSOURI RIVER.

● = TYPHOID FEVER CASES; TWO OR MORE DOTS WITHIN A CIRCLE INDICATE TWO OR MORE CASES IN SAME HOUSE.

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THE NORRIS PRINT'G CO. WASHINGTON, D. C.

under aseptic conditions by puncture of a vein at the elbow. The blood was transferred at once to a tube containing 20 cubic centimeters of sterilized ox-bile. The blood-bile mixture was incubated at 37° C. for from fifteen to twenty-four hours. Then four or five drops of the blood-bile mixture were pipetted onto a plate of lactose-litmus agar or plain agar.[a] The drops were spread over the first plate with a glass rod bent at a right angle. From the first plate the rod was rubbed over the surfaces of a second and a third plate, thus securing dilution. The plates then were incubated for eighteen to twenty-four hours and typhoid-like colonies were "fished" and planted in tubes of bouillon. Tubes which showed a typhoid-like growth were tested with antityphoid serum. If agglutination occurred, the tube was shaken to break up clumps and some of the contents plated out in order to obtain the organism in pure culture. After the organism was obtained in presumably pure culture it was carried through the various media on which the typhoid bacillus gives differentiative cultural characteristics.

The following table gives the results of the blood cultures:

TABLE No. 5.—*Showing results of blood cultures for B. typhosus.*

No.	Patient.	Definite onset of illness.	Clinical course.	Temperature when blood was taken (°F.).	Quantity of blood taken (c. c.).	Date of taking blood.	Result of culture.	Remarks.
1	E. W. (M., W., adult).	Mar. 19	Mild; no rose spots observed.	99.2	10	Apr. 1	−	Widal +; temperature curve descending for several days before blood was taken.
2	S. H. (M., W., aet. 29).	...do.....	Typical.....	101.4	5	Apr. 7	+	Widal +; temperature descending.
3	J. R. (M., W., aet. 22).	Mar. 29	Mild; rose spots (?).	101.0	5	...do.....	−	Do.
4	K. C. (M., Syrian; aet. 10).	Apr. 1	Typical.....	103.5	5	...do.....	+	Widal +.
5	J. R. (M., W., adult).	Feb. 20	Typical and long duration.	102.0	5	Apr. 9	+	Widal −.
6	T. B. (M., W., adult).	Mar. 20	Typical.....	100.6	5	...do.....	+	Widal +; temperature descending.
7	R. S. (M., W., adult).	Apr. 4	.....do.....	103.3	5	Apr. 8	+	Widal −.

[a] It is a considerable advantage, but by no means essential, to use for this plating Endo or some other medium selective for the typhoid group of organisms because by so doing the confusion and trouble occasionally resulting from contaminations with skin cocci or other organisms can be obviated to a large extent.

Judging by the results of the clinical observation of cases and of the laboratory tests, it seems probable that at least 85 or 90 per cent of the cases reported as typhoid fever during the outbreak were correctly reported as such.

In the canvass of about 100 homes, 8 or 10 cases were found which were clinically typhoid but which had not been reported. Therefore it appears reasonable to believe that fully as many cases of typhoid actually occurred as the record of reported cases showed. This view is supported by the fact that the proportion of deaths to cases was as high as is usual in extensive outbreaks of this character. The records show a report from December 1, 1909, to April 1, 1910, of 582 cases and 59 deaths, thus showing a case fatality rate of about 10 per cent.

IMPORTED CASES.

One of the many suggestions offered to explain in whole or in part the high rate of prevalence of the disease was that a large proportion of the cases reported had occurred in persons who had contracted the infection elsewhere and had come to Omaha after or a short while before onset of illness. Effort was made, therefore, to determine as accurately as possible the place of infection of the cases. The whereabouts of the persons affected during the thirty days prior to onset of illness and the probability of exposure to infection in each place were considered.

Of the 105 cases investigated only six gave a history of having been away from Omaha within thirty days prior to onset of illness. Of these six, one had not been in Omaha prior to onset of illness and undoubtedly contracted the infection elsewhere; one had been away from the city, nursing a case of typhoid fever for a period of six weeks ending eleven days before definite onset of illness, and probably contracted infection while away; and four had been away from Omaha for periods of less than one-fourth of the thirty days prior to illness and possibly contracted the infection while away, but more probably contracted the infection in Omaha.

The 105 cases may be classed as follows:

	Number of cases.
(1) Infection undoubtedly contracted in Omaha	99
(2) Infection probably (chances over 75 per cent) contracted in Omaha	4
(3) Infection probably (chances over 75 per cent) contracted away from Omaha	1
(4) Infection undoubtedly contracted away from Omaha	1
Total	105

Judging from these data it appears that over 95 per cent of the persons affected during the outbreak contracted the infection in the city of Omaha.

POSSIBLE SOURCES OF INFECTION.

The time of occurrence, the extent and the distribution of the outbreak indicated (1) that the infection had been spread under conditions of cold winter weather; (2) that some condition or set of conditions had arisen which were remarkably, and certainly very unusually, favorable to the causation of typhoid fever in that season of the year; and (3) that the city's population quite generally had been exposed to the infection. The following possible immediate sources of infection, therefore, were to be considered: (1) Water supply, (2) milk supply, (3) raw vegetables and fruits, (4) raw shellfish, (5) other food supplies, including ice cream, bakery products, etc., (6) ice supply, and (7) air (dust).

Personal contact, sewage disposal, and local sanitary conditions, also, were to be carefully considered as factors operating through the above-mentioned media or otherwise.

Flies as a considerable factor in the spread of the infection could be definitely excluded, because during the period in which the outbreak was caused there were certainly very few flies in Omaha, and these could not have been very active during the cold weather. Considered together, the season and the distribution of the disease preclude the likelihood that insects or any vermin could have constituted a very considerable factor.

ICE.

As the outbreak was caused for the most part during cold winter weather, it is unlikely that many of the persons affected had used ice in drinking water or in other ways by which organisms contained in the ice would have been swallowed.

Of the 103 cases considered to have contracted the infection in Omaha, which were investigated, only two gave a history of having habitually used ice in drinking water during the thirty days prior to onset of illness. One of these had used only the manufactured ice and the other was not certain whether the ice used was manufactured or natural.

A large part—possibly as much as 40 or 50 per cent—of the ice used in Omaha is natural ice. Some of this is harvested from nearby

lakes, but the greater part of it is harvested from the Missouri River. The ice harvested from the river, in all probability, contains fewer disease-producing organisms than did the water from which it was derived. Although ice may be eliminated beyond reasonable doubt as having been a considerable factor in the production of the outbreak, it should be borne in mind that ice harvested from polluted waters, as was most of Omaha's natural supply during the winter of 1909–10, may become, upon the advent of warm weather and consequent increased use of ice in beverages and foods, an important source of infection.

MILK.

The general features of the outbreak were not those usual to an extensive outbreak caused by milk-borne infection. There was no disproportionately large number of cases among children, and there appeared to be no unusually large number of instances in which two or more cases developed at about the same time in the same household. Yet some of the local physicians had become impressed with the fact that a large proportion of their typhoid patients were among persons who had used milk supplied by a certain dairy company which conducts a large retail business in Omaha, and expressed the view that the outbreak was caused by infection in the milk supplied by this company.

Special attention was given, in the course of the investigation, to the milk supply as being possibly the immediate source of the infection. In order to determine if there was any disproportionately large number of typhoid cases among the customers of any particular dairymen, a list of all the dairies in Omaha was made, giving, as accurately as could be ascertained, the amount of milk sold from each during the months of January, February, and March, 1910. Then, in the investigation of cases, careful inquiry was made to determine the sources of milk used during the thirty days prior to illness by the persons affected.

Of the 103 cases investigated, satisfactorily definite data as to use of milk during the thirty days prior to onset of illness were obtained from 99. Of these, 18 gave a history of not having used milk in any way, 4 of having used only milk which was boiled subsequent to purchase, 3 of having used milk only as ice cream, 5 of having used milk only from their own or a neighbor's cows, and the remaining 69 cases were distributed among the customers of 30 different dairymen.

The 103 cases gave the following history as to the way in which milk was used prior to illness:

How used:	Number of cases.
As a beverage	[a] 28
On fruits or cereals, but not as beverage	33
In hot coffee or tea only	18
As ice cream only	3
Not in any way	18
Not determined	3
Total	103

Of the cases which used milk as a beverage, 4 used boiled milk exclusively.

The milk supply of Omaha is distributed from about 70 dairies located in or near the city. Two dairies, A and B, are controlled by companies and do a large business. About 50 per cent of the milk consumed in Omaha is distributed from these two dairies. Most of the milk from dairy A is retailed, about 5,000 households being supplied directly from this dairy; while most of the milk from dairy B goes into the wholesale trade, being distributed to hotels, restaurants, groceries, bakeries, etc. At both dairies (A and B) milk cans and bottles are sterilized. About 95 per cent of the milk distributed from dairy A is pasteurized; the remaining 5 per cent is obtained from special farms and is "certified." The whole output from dairy B is pasteurized.

The work at both these dairies is supervised as thoroughly as practicable by the health officer. An inspector from the health office makes frequent visits, usually daily and sometimes on several occasions within a day, to each of the plants.

The health officer appears to have been commendably energetic in his effort to get a safe milk supply for Omaha. Besides supervising the work at these two large dairies, he is apparently using to the best practicable advantage his too limited force of inspectors to

[a] It is instructive to compare this percentage (27) with the percentages of cases which gave a history of having used milk as a beverage among those investigated in Washington, D. C., in 1906, 1907, and 1908. Thus:

Year.	Number of cases investigated.	Percentage used milk as beverage.
1906	747	65
1907	523	55
1908	542	42
Average		54

See Hygienic Laboratory Bulletins: No. 35, p. 61, for 1906; No. 44, p. 46, for 1907; No. 52, p. 100, for 1908.

bring about improved sanitary conditions and safer methods of handling milk at the farms and small dairies from which the rest of the city's milk supply comes.

Of the 103 cases of typhoid fever investigated, the number of cases among the customers of the different dairymen was roughly proportionate to the amount of milk sold by the dairymen. No one of the dairymen had a number of cases among his customers sufficiently out of proportion to amount of milk sold to warrant a reasonable suspicion that the milk sold by him was the source of the infection.

Twenty-four of the 103 cases gave a history of having used regularly or occasionally within the thirty days prior to illness milk supplied from dairy A. This number, at first glance, seems large, and it was the output from this dairy that some of the local physicians, as referred to above, had regarded as the source of infection. But when this number, composing about 23 per cent of the cases investigated, is considered in connection with the fact that about 35 per cent of the milk retailed in Omaha is distributed directly or indirectly from this dairy, it becomes evident that the number was not even large enough to show that the incidence of the disease was as great among persons supplied with milk from this dairy as it was among the general population of the city.

In this connection, it should be borne in mind that the proper sterilization of milk bottles and the pasteurization of milk may be something of a safeguard to a community when visited by an outbreak of typhoid fever even caused solely by water-borne infection, because if the infectious organisms in the water find their way into milk, as they are almost sure to do from time to time if the cans and bottles are washed in the polluted water and not sterilized before being used as containers for the milk, they may undergo there tremendous multiplication and so be conveyed to the people in much larger doses than they probably ever would be conveyed by the water directly.[a]

From the foregoing data it appears that the milk supply can be definitely eliminated as having been the chief and primary or even a considerable factor in the production of the outbreak.

ICE CREAM.

A large proportion of the ice cream used in Omaha is made from pasteurized cream. The raw cream used for making ice cream is supplied almost, if not quite, wholly from dairies from which milk is distributed in the city.

Of the 103 cases investigated only 12 gave a history of having eaten ice cream within the period of thirty days prior to illness. These 12

[a] Hygienic Laboratory Bulletin No. 56, "Milk and Its Relation to the Public Health," p. 157.

cases were distributed among the customers of several ice-cream producers.

It is evident from these data that ice cream was not a considerable factor.

RAW SHELLFISH.

The following table gives the history of the 103 cases in regard to the eating of raw oysters and clams within the thirty days prior to illness:

Shellfish.	Yes.	No.	Not determined.	Total cases.
Oysters	7	91	5	103
Clams	0	98	5	103

The small proportion of cases giving a history of having eaten oysters or clams shows that raw shellfish could not have been an important factor in the production of the outbreak.

RAW VEGETABLES.

The following table gives the history of the 103 cases in regard to the eating of celery and lettuce within the thirty days prior to illness:

Raw vegetables.	Yes.	No.	Not determined.	Total cases.
Celery	41	57	5	103
Lettuce	24	74	5	103

These figures show that the majority of the cases certainly could not have been caused by infection in either the celery supply or the lettuce supply.

Most of the celery sold in Omaha during the winter was obtained from truck farms in sections of Michigan and of Southern States. From these same sections no doubt other American cities, some of which did not have during the past winter any unusual occurrence of typhoid fever, also obtained a part of their supply of celery. Most of the lettuce sold in Omaha during the winter was leaf lettuce raised in hothouses, located in Iowa and Nebraska. Some—the head lettuce—was obtained from truck patches in the South. Some of the other cities and towns using lettuce from the same sections of the country did not have typhoid outbreaks. From a consideration of the foregoing, it does not appear reasonable to believe that celery and lettuce could have been a very important factor in the production of the outbreak in Omaha.

BAKERY PRODUCTS AND OTHER GENERAL FOOD SUPPLIES.

In view of the complex conditions under which the general food supplies of the average city are prepared and distributed, the number of persons through whose hands they pass, and the readiness with which typhoid infection may be carried from the bedsides of patients and from the excreta of bacillus carriers, it is almost inconceivable that these food supplies do not play some part in the spread of infection after the infection has been introduced into a city and widely disseminated among the people. But considering the general features of the outbreak and the fact that the conditions under which the food supplies were handled during the period in which the outbreak was caused, were, so far as could be ascertained, either better or certainly no worse than in previous years, it does not seem reasonable to suppose that bakery products and other general food supplies could have played more than a secondary and relatively small part in the production of the outbreak in Omaha.

DUST.

As the ground at Omaha was covered with snow from December 3, 1909, to February 1, 1910—that is, during the greater part of the time in which the outbreak was caused—it does not seem possible that much of the infection could have been disseminated in air-borne dust. Furthermore, if dust had been abundant it would still be difficult to conceive of any source from which infection sufficient to cause such an outbreak could have been carried in the dust.

SEWAGE DISPOSAL AND GENERAL SANITARY CONDITIONS.

The greater part of the city is provided with a water-carriage sewerage system. Exact data on the subject were not obtainable, but it is estimated that about two-thirds of the houses in the city are connected with the city sewerage system. The main sewers empty the sewage entering the water-carriage system into the Missouri River. Three of these main sewers discharge into the river at points along the city's water front. One discharges into Papillion Creek and thence into the river below (south of) the city, and one discharges into the river at a point above (north of) the city and about 8 miles upstream from one of the intakes for the city's water supply. (See Map No. 4, and p. 36 under head of "Water.") Thus Omaha, consistent with the practice followed by many other cities on the Missouri River, uses this river both as a sewer and as a source of water supply, even going so far, by having one of the intakes for its water supply below the outlet of one of its main sewers, as to partake in its own drinking-water supply some of the sewage which it contributes to the general pollution of the river.

In view of the rapidly increasing population along the great water courses of the United States, and the frequently demonstrated fallacy of the belief that running water adequately purifies itself of dangerous sewage pollution, it certainly seems time for action to be taken by interurban or interstate agreement to have the different streams used either as sources of water supply or as sewers, and not for both purposes.

The Missouri-Mississippi River and the other great interstate water courses seem to present, at the present time, a large and very important field of action for the health forces of the National Government. The investigation of these water courses in respect to sewage pollution and to their use as sources of water supply certainly could be conducted by the agents of the national health organization in such a way as to obviate any reasonable criticism that the methods followed and the conclusions reached were being influenced by local (or state) prejudice.

Furthermore, if the different laboratories necessary to the investigation were equipped from the same national appropriation and their personnel were responsible to the same central head it is obvious that the work could be done more economically, more consistently, and, so far as expense to the different States affected would be concerned, more equitably than it could be done by the health organizations of the different States working either independently or cooperatively.

As the pollution of these water courses affects the commercial welfare of the communities using these water courses as sources of water supply—particularly and specifically by affecting the health of personnel of vehicles operated by common carriers—and as the pollution in water supplies will certainly from time to time find its way into and dangerously contaminate and render impure many of the various beverages and foods (dairy products particularly) such as are usually handled in the course of interstate traffic, the investigation and control of the sewage pollution of these water courses would appear to come thoroughly within the scope of the constitutional powers of the Congress of the United States to regulate interstate commerce.

All of the residences inspected in Omaha which were not connected with the water-carriage sewerage system were found to be provided with either cesspools or privies, cesspools (or "privy vaults") being vastly in the majority. Very few of the cesspools were found to be water-tight, most of them being merely holes dug in the ground to a depth of about 6 feet. In a few instances there appeared to be a likelihood of seepage from the cesspool to nearby wells, but evidence was lacking that such seepage contributed much to the spread of infection during the outbreak.

The incidence of the disease appeared to be as great among persons living at residences connected with the city's sewerage system as among those living at residences provided with cesspools. Of the 103 cases investigated 68 were among persons living at residences connected with the city sewerage system and at which there were water-closets, 34 at residences not connected with the city sewerage system and at which there were cesspools or privies, and 1 at a residence where the method of sewage disposal was not noted. Of the 68 cases at residences connected with the city sewerage system, 58 were at residences having water-closets in the house only, and 10 at residences having water-closets in the yard only.

In the investigation of the 103 cases, nine instances were met with in which two or more cases had developed in the same residence. Of these nine instances, six were at homes connected with the city sewerage system and three at houses provided with cesspools or privies; so it appears that secondary cases were not much, if any, more frequent among persons living at houses provided with cesspools or privies than among those living at homes connected with the city sewerage system.

In the following table is given the general sanitary condition of the residences at which the persons who furnished the 103 cases investigated had lived at the time when the infection was presumably contracted:

Condition of residence.[a]	Number of cases.	Per cent of cases.
Good	22	21.4
Fairly good	37	36.0
Rather bad	29	28.1
Bad	14	13.6
Not determined	1	.9
Total	103	100.0

[a] The definitions of the terms used in this table correspond to those used in Hygienic Laboratory Bulletin No. 35, Report No. 1, on the "Origin and Prevalence of Typhoid Fever in the District of Columbia," p. 46.

From the foregoing data it is evident that the chief factor in the production of the outbreak was not dependent for its operation upon insanitary conditions at places of residence of persons affected.

CONTACT.

Of the 103 cases investigated, 14 gave a history of association during the thirty days prior to onset of illness with previous cases in the febrile stage of the disease, and were attributable to infection by personal contact.

As the cases investigated were reported subsequent to February 28 it is probable that the percentage of secondary or contact cases

was higher among them than it was among those occurring in the early part of the outbreak.

Few facts in the epidemiology of infectious diseases have been more definitely established than has the fact that when typhoid infection is introduced into a community, no matter through what channels, and the disease continues to prevail extensively for some time, personal contact or contagion sooner or later will become, unless specific and rigid precautions be taken to prevent it, an important factor in the spread of the infection.

The outbreak at Omaha was not exceptional in this respect and personal contact beyond reasonable doubt did operate to some extent as a factor in the spread of the infection; but in view of the extent and the explosive character of the outbreak, the percentage of cases among those occurring even toward the end of the outbreak which gave a history of association with previous cases, and the fact that without any extraordinary precautions having been taken to prevent infection by personal contact, the disease, after becoming widely disseminated over the community, suddenly began to decline and soon reached a point which may be called "normal" for the community at that season, it is evident that in the production of this outbreak personal contact operated only as a factor secondary to some other factor which was chief and primary.

WATER.

The general water supply of Omaha is obtained from the Missouri River. It is estimated that about four-fifths of the houses in the city proper are connected with this water supply and that probably about 90 per cent of the population use the river water as the sole or principal supply for drinking and culinary purposes. There are a number of wells and a few springs still in use, but these are for the most part in the outskirts of the city, and all of them, so far as was ascertained, are on private property.

Of the 103 cases investigated, 98, or about 95 per cent, gave a definite history of having used the unboiled Missouri River water supplied through the regular city system as the sole, principal or occasional source of water for drinking purposes during the thirty days prior to onset of illness. The following table gives the sources of water used for drinking during the thirty days prior to illness by the 103 persons affected and whose cases were investigated:

Water:	Number of cases.
Raw tap—	
Solely	51
Principally	21
Occasionally	26
Occasionally(?)	3
Boiled tap—	
Solely	1
Principally	21
Occasionally	15
Private wells or springs in Omaha—	
Solely	1
Principally	7
Occasionally	5
Bottled and vended—	
Solely	0
Principally	1
Occasionally	0
Various sources out of Omaha—	
Solely	0
Principally	0
Occasionally	4

Of the 30 cases which gave a history of having used solely or principally for drinking the boiled tap, well or spring, or bottled waters, 9, or 30 per cent, were in persons who had been in the thirty days prior to illness in free association with previous cases in the febrile

stage of the disease and were attributable to infection by personal contact. The relatively large percentage of contact histories in this group of cases is somewhat significant, in that it suggests that when the raw tap water as a possible factor in the distribution of the infection could be to some extent eliminated, other factors took a more prominent place.

Of the cases listed as having used principally for drinking water other than the raw tap water, the vast majority were in persons who did use in considerable amount the unboiled tap water for drinking, many of them being school children and other persons who used for drinking boiled tap, well or spring, or bottled water at their homes, but who drank the raw tap water at the public schools or at their places of occupation.

The school board did not see fit to take action at any time during the outbreak to provide water other than the raw tap for use in the public schools. If this water were the source of the infection which caused the outbreak it is almost certain that some of the cases in school children resulted from the use of unboiled water at the public schools. Furthermore it may be expected that certain families were influenced to discontinue or not to begin boiling the water for use at their homes by reason of the fact that their children were given the unboiled water to drink at the public schools. Several instances of this kind were learned of definitely in the course of visits to homes for the investigation of cases.

The public water supply of the city has been owned and controlled for the past twenty years or more by a private company known as the "Omaha Water Company." A year or so ago the city authorities took steps to take over from the water company the control and ownership of the water-supply system, but the terms of assessment of the property could not be agreed upon and the matter was taken before the courts for adjudication, and was still pending before the courts at the time of the outbreak. This circumstance added somewhat to the complexity of the situation, particularly in respect to the adoption of measures for the improvement of the water supply.[a]

The city's water supply is taken from the river at two points (see Map No. 4), one, the north intake, being a few feet from the bank of the river at Florence, and the other, the south intake, being about 250 feet out in the river nearly on a line leading east from the foot of Burt street. About 20,000,000 gallons of water from the river are supplied to the city daily; of this amount about 16,000,000 gallons are pumped from the north or Florence intake, and about 4,000,000 gallons from the south or Burt street intake. At each station the water passes through several settling reservoirs, the capacity of these reservoirs and the rate of flow through them being

[a] See Appendix, p. 50.

such as to give the water storage for about six hours (estimated). In the second reservoir of the series at each station a coagulant (alum) is applied to the water. The river water is very turbid, but the coagulant and the storage, even for such a short period, effect a marked reduction in the turbidity and also a considerable reduction in the bacterial content of the water. The process can not be regarded, however, in view of the results of the bacteriologic examinations given below, as being sufficient to render the water reasonably free from whatever dangerous pollution it may contain.

From the Florence reservoirs the water is pumped to the Walnut Hill reservoir (see Map No. 4), which is located at a relatively high elevation in the western part of Omaha and serves as a standpipe from which pressure is supplied for distributing the water to the city. The main from the Burt street reservoirs extends to the Walnut Hill reservoirs. There appeared to be some difference of opinion among the local engineers as to whether any of the water from the Burt street station was pumped during the period of the outbreak as far as the Walnut Hill reservoir, but the officials of the water company, who were certainly in a position to be correctly informed on that subject, positively asserted that none of the water from the Burt street station had reached the Walnut Hill reservoir at any time within the ten years preceding the investigation in April, 1910. These officials state that all the water taken in at the Burt street station is limited in its distribution to the relatively unelevated and eastern section of the city bounded on the north by Lake street, on the west by Sixteenth street, and on the south by Leavenworth street. When the pump at the Burt street station is stopped, as it frequently is at night—this Burt street supply being used only as an auxiliary to the principal supply from the Florence station—the mains in this section of the city are supplied with water from the Walnut Hill reservoir. Therefore, according to information received from the manager of the water company it is clear that while the water from the Florence intake is distributed over all parts of the city connected with the water system, the water from the Burt street intake is distributed only to the eastern, relatively unelevated section of the city, referred to above.

BACTERIOLOGIC EXAMINATION OF THE MISSOURI RIVER WATER SUPPLY.

The technique followed in making the bacteriologic examinations of the water was that recommended by the committee on standard methods of water analysis of the American Public Health Association on January 9, 1905.

The laboratory of the Creighton Medical College, where the bacteriologic work was done, did not have facilities for the use of gelatin plates, so that in making the bacterial counts agar plates were used.

The colonies were counted after the plates had been kept at 37° C. for forty-eight hours from the time of seeding. For most waters it is understood that agar plates kept at 37° C. will average considerably lower counts than will gelatine plates kept at 20° C. The press of other work made it impossible at the time to conduct a very exhaustive bacteriologic study of the water, but enough was done to form a satisfactorily definite idea of the bacterial content of the water and the degree of improvement of the water effected by the storage and use of coagulant at the two systems of reservoirs. The samples of water examined were taken from (*a*) the inlet to the first storage reservoir at the Florence station; this representing the water from the river as it entered the Florence intake; (*b*) the outlet from the last in the series of storage reservoirs at Florence; this representing the water after storage and treatment with a coagulant in the Florence system of reservoirs and just as it started to the Walnut Hill reservoir for distribution to the city; (*c*) the inlet to the first storage reservoir at the Burt street station; this representing the water from the river as it entered the Burt street intake; (*d*) the outlet from the last in the series of storage reservoirs at the Burt street station; this representing the water after storage and treatment with a coagulant in the system of reservoirs at the Burt street station and as it was delivered to the mains for distribution to the city; (*e*) the tap at the bacteriological laboratory of the Creighton Medical College located on the northeast corner of Fourteenth and Davenport streets; this representing a mixture of the effluents from both the Florence and Burt street reservoirs after the water had traversed the city mains for some distance.

In the following tables, A, B, C, D, and E, are given the results of the bacteriologic examinations of these samples of water:

TABLE A.—*Samples of (river water) influent to Florence system of reservoirs.*

Date of examination.	Number of bacteria in 1 c. c.	Fermentation in lactose bouillon.		B. coli in—	
		10 c. c.	1 c. c.	10 c. c.	1 c. c.
1910.					
April 5	3,840	+	+	(?)	(?)
April 6	4,600	+	+	(?)	(?)
April 7	3,600	+	+	(?)	(?)
April 8	9,200				
April 15	5,400	+	+	+	+
April 18	11,400	+	+	+	+
Average	6,340	100%+	100%+	100%+	100%+

TABLE B.—*Samples of effluent from Florence system of reservoirs.*

Date of examination.	Number of bacteria in 1 c. c.	Fermentation in lactose bouillon.		B. coli in—	
		10 c. c.	1 c. c.	10 c. c.	1 c. c.
1910.					
April 5	260	+	+	+	+
April 6	300	+	+	(?)	(?)
April 7	(a)	+	−	(?)	−
April 8	200	+	Bubble.	(?)	−
April 15	220	+	+	(?)	−
April 18	540	+	+	+	+
Average	304	100%+	66%+	100%+	40%+

a Plates overgrown; "spreaders."

TABLE C.—*Samples of (river water) influent to Burt street system of reservoirs.*

Date of examination.	Number of bacteria in 1 c. c.	Fermentation in lactose bouillon.		B. coli in—	
		10 c. c.	1 c. c.	10 c. c.	1 c. c.
1910.					
April 5	4,600	+	+	(?)	(?)
April 6	5,800	+	+	(?)	(?)
April 7	(a)	+	+	(?)	(?)
April 8	(a)				
April 15	4,600	+	+	+	+
April 18	11,600	+	+	(?)	(?)
Average	6,650	100%	100%+	100%+	100%+

a Plates overgrown from 0.005 c. c.

TABLE D.—*Samples of effluent from Burt street system of reservoirs.*

Date of examination.	Number of bacteria in 1 c. c.	Fermentation in lactose bouillon.		B. coli in—	
		10 c. c.	1 c. c.	10 c. c.	1 c. c.
1910.					
April 5	(?)	+	−	+	−
April 6	240	+	+	(?)	(?)
April 7	240	+	−	(?)	−
April 8	(a)	+	+	(?)	(?)
April 15	280	+	+	+	+
April 18	1,700	+	+	+	+
Average	615	100%+	66%+	100%+	50%+

a Plates overgrown; "spreaders."

TABLE E.—*Samples of water from tap at laboratory on corner of Fourteenth and Davenport streets.*

Date of examination.	Number of bacteria in 1 c. c.	Fermentation in lactose bouillon.			B. coli in—		
		10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	0.1 c. c.
1910.							
April 1	160	+	−	.....	(?)	−	.....
April 2	220	+	−	.....	+	−	.....
April 16	320	+	+	−	+	+	−
April 19	520	+	+	.....	(?)	(?)	.....
Average	305	100%+	50%+	0%+	100%+	33%+	0%

It should be noted that these examinations were made on and after April 1, which was subsequent to the period of causation of the typhoid outbreak. A number of samples of the water examined during January and February, when the outbreak was at its height, showed, according to the results of Doctor Langfeld, the city bacteriologist, a considerably higher bacterial count than the average for the above.

THE MISSOURI RIVER WATER SUPPLY AND ITS RELATION TO THE TYPHOID OUTBREAK.

The Missouri River at numerous points north of Omaha receives the sewage from a large number of persons, and therefore can be reasonably regarded as a somewhat dangerously polluted stream. The nearest large city to the north of Omaha which discharges its sewage directly into the river is Sioux City, Iowa. Sioux City is about 90 miles upstream from Omaha and has a population of about 50,000. Along the watershed of the Missouri between Sioux City and Omaha there are a number of towns and villages, from many of which sewage finds its way into the river, either directly from sewers or overhanging privies or indirectly by surface washings or through streams tributary to the Missouri River. The water of the Missouri presents a decidedly turbid appearance, and in popular parlance the river is frequently referred to as "Old Muddy." The suspended matter appears to be made up largely of loam, clay, and fine sand. It is comparatively heavy, and when the water is allowed to stand it settles rapidly. Accurate turbidity readings were not made, but in a liter flask filled with the water and violently agitated and then kept at rest for five to ten minutes about 90 per cent, at a rough estimate, of the suspended mud will settle to the bottom. The high turbidity of the water, though objectionable from an esthetic standpoint, is probably, from a strictly sanitary standpoint, a considerable advantage, because it seems reasonable to believe that the mud in streaming constantly through the water must carry down with it a considerable proportion

of whatever pathogenic organisms chance to be suspended in the water. The process may be regarded as one of natural filtration; the sand in this instance streams through the water, and so is the reverse of the process in artificial filtration, where the water streams through the sand.

LOCAL SEWAGE POLLUTION OF THE OMAHA WATER SUPPLY.

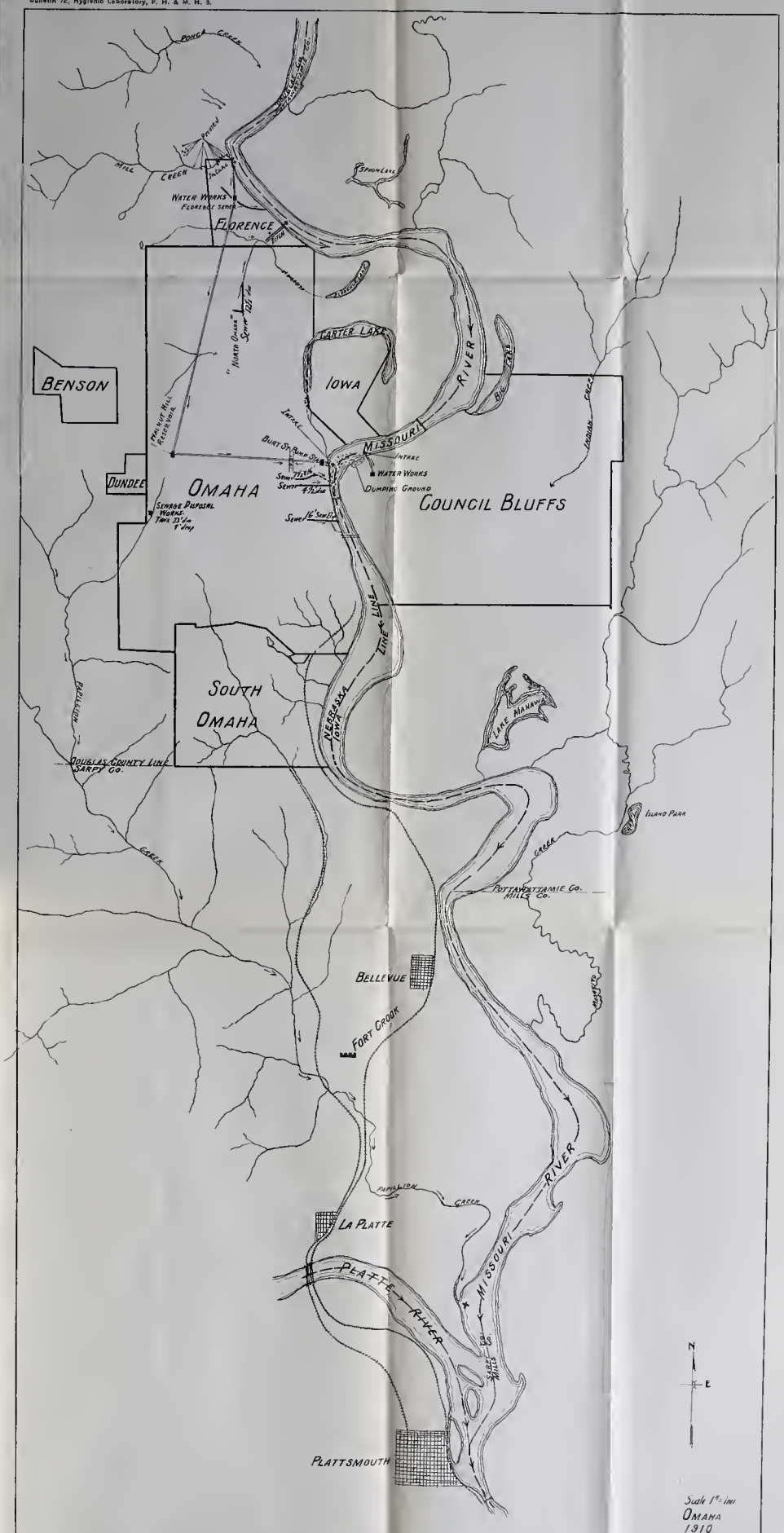
Besides the large volumes of sewage known to enter the river at points farther upstream, the investigation revealed evident and gross pollution of the water with human sewage at points within 8 miles above each intake for the city's water supply. The mouth of Mill Creek empties into the river at a point about 500 feet above the Florence intake. This creek carries into the river the drainage from a number of cesspools or privies and from a number of stable-manure dumps, etc. (See Map No. 4.) About 12 of the cesspools or privies are located on the banks of the creek within half a mile—1 within 40 feet—of the creek's mouth. Considering the proximity of the creek's mouth to the intake and the evident direction of the currents in that part of the river, the contents of this creek undoubtedly constitute a dangerous source of contamination for the water entering the Florence intake.

Below the Florence intake and above (upstream from) the Burt street intake the river was found to receive gross sewage pollution from several different sources. (See Map No. 4.)

(1) The main sewer from Florence passes under the Florence storage basins and discharges the sewage of several hundred persons into the river at a point about 1 mile below the Florence and about 9 miles above the Burt street intake.

(2) The North Omaha sewer, conveying the sewage from about 5,000 persons, including the occupants of a hospital, living in the northwest section of the city of Omaha, discharges into the river at a point about 8 miles above the Burt street intake. Previous to June 8, 1909, this North Omaha sewer discharged into Florence Lake. On that date a ditch (see Map No. 4) was completed, and since then the sewage from this sewer has been conveyed through the ditch directly into the river. Hence the winter of 1909–10 was the first winter in which the water at the Burt street intake had been polluted with the discharge from this large sewer.

(3) An extensive dumping ground of Coucil Bluffs, Iowa, on the east side of the river, drains certainly to some extent, and at times of heavy rains to a very considerable extent, into the river at points from a half to three-quarters of a mile upstream from the Burt street intake. This ground receives the usual dumpings from a city, such as ashes, rubbish, etc., and also dead animals and the night-soil from a large number of privies. At one place in the dumping ground there



Map No. 4, of Omaha, Nebraska, and Vicinity, Outlining Water-Supply and Sewerage Systems

was observed a large heap which partially hung over the bank of the river and which was composed in considerable part of unmistakable privy contents. In order to determine definitely if the drainage from this particular heap was carried to any extent to the point in the river at which is located the Burt street intake, floats, some on the surface, some partially submerged, and some entirely submerged, were placed in the river just under the dump heap and followed downstream by several of us in a boat. Most all of the floats were carried by the current, with all the definiteness of a laboratory experiment, immediately over or within 100 feet of the Burt street intake.

(4) A number of privies, about 10 or 12, are located on the Omaha side of the river within a few hundred feet of the Burt street intake. In times of high water it is very probable that the contents of some of these privies contribute to the contamination of the water entering the intake.

From these observations it was evident that the water received from the Burt street intake was at the time of the outbreak exposed to much greater sewage pollution from comparatively near-by sources than was the water received from the Florence intake. In this connection the fact that the disease appeared to be particularly highly prevalent among persons who habitually used for drinking the water in the section of the city to which the distribution of the Burt street supply was confined becomes of striking significance. According to information received from the manager of the Omaha Water Company, practically none of the water from the Burt street station was supplied to any part of the city outside of the section, previously referred to, bounded on the north by Lake street, on the west by Sixteenth street, and on the south by Leavenworth street. This section contains a number of industrial establishments, but has less than one-tenth of the city's population. Of the 103 cases investigated, 65, or over 63 per cent, were among persons who resided in, had their place of occupation in, or both resided and had their place of occupation in this section. Thus the 10 to 20 per cent or less of the population habitually using for drinking purposes the water supplied in this section of the city furnished over 63 per cent of 103 cases investigated, in the order in which they were reported from the whole city.

CONDITIONS IN THE RIVER WHICH MAY HAVE AFFECTED THE AMOUNT AND DEGREE OF INFECTION IN THE WATER.

If the outbreak in Omaha was caused by the pollution of the Missouri River water, the question which naturally arises, since the people had been using the polluted river water for years, is, Why had not similar extensive outbreaks occurred before? The answer to this question may be found in one, or, perhaps to some extent, in all of the following hypothetical conditions:

(1) The specific organisms which cause typhoid fever may have been introduced into the water in unusually large numbers.

(2) The organisms when introduced into the water may have been of an unusually high degree of infectiveness, or they may have become so after getting into the water.

(3) The river may have afforded conditions which were unusually favorable to concentration in the water of such organisms as were introduced.

(4) Conditions in the river water may have been unusually favorable to the viability of the organisms.

In support of the view that the organisms were introduced in unusually large numbers is the fact that a part of the city's water supply (the Burt street station supply) was exposed during the winter of 1909–10 to more sewage contamination (that from the North Omaha sewer having been added) than it had been in any other winter for certainly a good many years.

In support of the view that the conditions in the river water were unusually favorable to the concentration and perhaps also the life of the causative organisms are the following facts:

(1) The condition of the river during the winter of 1909–10 was very unusual. A heavy rain beginning on November 12 continued for three or four days; the fall during this period was over 4 inches. These heavy rains must have washed into the current of the river a large amount of sewage and other matter which had accumulated on the watershed of the river above Omaha during the summer and fall. Judging by the report of cases, the beginning of the unusually high prevalence of typhoid fever was (by onset of illness of cases) about November 25, or about twelve days (the usual incubation period) after the occurrence of the heavy rains.

Soon after the heavy rains the cold weather set in. By December 10 the river at Omaha was practically covered with ice from side to side. The river continued frozen over until March 4, 1910, when the breaking up of the ice at Omaha began. According to statements obtained from a number of observers, this was the first winter within the past fifteen or twenty years that the river at Omaha had remained frozen over for any considerable period. Tremendous volumes of floating ice were going down the river from March 4 to about March 10, when the river became practically clear of running ice.

During the freeze the volume of water coming down the river must have been reduced very considerably below the normal, so that whatever sewage entered the current caused more concentrated pollution than it would have caused in the normal volume of water. As the thawing began, the volume of water in the river of course became increased. The flooding and overflow of the river banks began about March 15, and reached the maximum on March 22. By April 1 the

river was again well within its banks and had resumed what may be called its usual condition for the season. It is readily conceivable that during this marked increase in the volume of the river, whatever dangerous pollution was in the water became markedly diluted—even allowing for what was washed from without the banks by the overflow—and was carried rapidly down the river. It is therefore reasonable to expect that with the beginning of the thaw and the rise in the river, there was a lessened concentration of dangerous pollution in the water. When the river subsided it may be readily conceived that in the reduced volume of water the pollution did not again become concentrated to the same extent as it had been before the thaw, because there was then less pollution to meet the reduced volume of water, the vast bulk of polluting matter having been washed away by the freshets.

Judged by the report of cases, the typhoid outbreak in Omaha rapidly declined from about March 25. Allowing for an incubation period of ten days or two weeks, this means that the chief cause of the outbreak became markedly diminished in its operation about March 10 or 15, which was coincident with the floodings of the river. The unusual condition of the river being followed so remarkably by an unusual occurrence of typhoid fever among persons drinking the water strongly suggests cause and effect.

(2) The reports showed that in other communities using water supplied from the Missouri River the typhoid fever rate was unusually high in the winter of 1909–10, while in communities neighboring these, but using water from other sources such as lakes, springs, wells, etc., the typhoid fever rate generally was not unusually high.

In the following table is summarized the information received from the different health departments of the several towns and cities:

TABLE NO. 6.—*Typhoid fever in towns and cities in the vicinity of Omaha.*

Town or city.	Estimated population.	Source of water supply.	Typhoid fever reported— Month.	1905.		1906.		1907.		1908.		1909.		1910.		Remarks.
				Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	
Council Bluffs, Iowa...	38,000	Missouri River....	January...	....	....	....	....	....	1	....	....	....	....	(?)	3	Water undergoes short storage and treatment with coagulant (alum). Intake for supply about three-fourths of a mile upstream from line on which is Burt street intake for Omaha's supply. Typhoid fever in Council Bluffs said by health officer to have been much more prevalent in winter of 1909-10 than in any other winter within last fifteen or twenty years.
			February .	....	....	....	....	....	2	....	....	....	....	52	3	
			March.....	....	....	....	....	....	1	....	....	....	....	21	2	
			April.....	....	1	....	....	....	....	....	....	....	1	....	....	
			May.....	....	....	....	....	....	....	....	....	....	1	....	....	
			June.....	....	....	....	....	....	....	....	....	....	....	....	....	
			July.....	....	....	....	....	....	....	....	....	....	1	....	....	
			August....	....	....	....	....	....	....	....	....	....	1	....	....	
			September	....	2	....	1	....	....	....	2	....	....	....	....	
			October...	....	....	....	....	....	....	....	....	....	....	....	....	
			November	....	2	....	....	....	....	....	1	....	1	....	....	
			December.	....	....	....	....	....	2	....	1	....	2	....	....	
Total.....	.....	.....	.....	....	5	....	1	....	6	....	4	....	7	....	....	
Nebraska City, Nebr...	7,380	Missouri River ...	.....	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	No record of cases and deaths for previous years, but Health Officer Dr. F. S. Marnell, in a letter dated March 31, 1910, stated as follows: "In the months of January, February, and March (1910) there were (in Nebraska City) 24 cases of typhoid fever, with 2 deaths. * * * This is the largest number of cases in any one year for the last six to my knowledge. No cases occurred after the ice went out of the river. The city water supply comes from the (Missouri)

																	River, and while no definite investigations were made 1 case occurred in a family where all but the one taken sick drank boiled water."
Kansas City, Mo	340,000	do	January	(a)	(a)	3	2	5	4	6	2	15	1	138	17	Typhoid fever evidently was unusually highly prevalent in January, February, and March, 1910.
			February	(a)	(a)	7	1	6	3	9	4	26	2	112	21	
			March	(a)	(a)	6	2	13	1	10	2	25	2	52	12	
			April	(a)	(a)	7	3	6	4	7	4	15	1	....	....	
			May	(a)	(a)	....	....	6	3	8	....	9	1	....	....	
			June	(a)	(a)	4	....	4	4	2	....	8	2	....	....	
			July	(a)	(a)	8	6	....	7	8	2	6	3	....	....	
			August	(a)	(a)	19	6	9	6	7	1	14	6	....	....	
			September	(a)	(a)	41	5	19	7	14	1	24	4	....	....	
			October	(a)	(a)	21	5	13	3	3	1	32	2	....	....	
			November	(a)	(a)	15	1	17	5	20	2	32	3	....	....	
			December	(a)	(a)	5	3	4	4	5	1	24	3	....	....	
Total				....	....	136	34	102	51	99	20	230	30	....	....	
St. Joseph, Mo	125,000	Missouri River	January	....	1	(a)	1	(a)	....	....	2	....	....	1	2	Water supply from river passed through sedimentation basins and mechanical filter; notwithstanding this treatment of the water typhoid fever appears to have been considerably more prevalent than usual for the winter season in the winter of 1909-10.
			February	....	1	(a)	....	(a)	....	....	....	....	....	1	1	
			March	....	....	(a)	1	(a)	2	....	1	....	....	1	2	
			April	....	1	(a)	1	(a)	2	....	1	2	2	....	....	
			May	....	....	(a)	....	(a)	1	....	....	2	2	....	....	
			June	....	....	(a)	1	(a)	2	....	1	1	1	....	....	
			July	....	....	(a)	1	(a)	1	9	1	....	....	....	....	
			August	....	2	(a)	....	(a)	1	9	3	2	....	....	....	
			September	....	2	(a)	2	(a)	1	4	4	....	1	....	....	
			October	....	2	(a)	3	(a)	1	2	1	1	2	....	....	
			November	....	2	(a)	3	(a)	2	1	....	1	4	....	....	
			December	....	....	(a)	1	(a)	1	2	....	1	2	....	....	
Total				....	11	....	14	....	14	27	14	10	14	....	....	

[a] No record.

TABLE NO. 6.—*Typhoid fever in towns and cities in the vicinty of Omaha*—Continued.

Town or city	Estimated population.	Source of water supply.	Month.	Typhoid fever reported—												Remarks.
				1905.		1906.		1907.		1908.		1909.		1910.		
				Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	
St. Louis, Mo.....	735,000	Mississippi River, but a large proportion of the water in that part of the Mississippi River comes from the Missouri.	January...	20	6	26	7	4	5	23	5	24	1	35	9	Water supply passed through large storage basins and treated with a coagulant (lime and sulphate of iron). This treatment is said to effect a very marked improvement in the water. It appears that typhoid in 1910 was somewhat more prevalent in January, February, and March than usual for that season.
			February .	14	6	17	5	15	6	19	3	14	3	17	3	
			March.....	19	4	20	6	14	2	11	2	17	7	23	9	
			April.....	....	6	17	5	15	3	11	6	12	1	....	....	
			May.....	12	9	12	3	19	2	15	1	15	6	....	....	
			June.....	15	....	14	3	25	4	33	5	30	5	....	....	
			July.....	59	18	50	8	36	8	161	14	63	9	....	....	
			August....	130	24	154	16	119	12	152	16	140	10	....	....	
			September	163	17	125	29	130	17	130	11	130	27	....	....	
			October...	103	23	101	14	92	24	69	12	108	13	....	....	
			November	63	8	50	10	56	12	33	9	63	9	....	....	
			December.	36	6	24	5	35	7	27	10	45	10	....	....	
Total.....	.....	.....	.....	634	127	610	111	560	102	684	94	661	101	....	....	
Sioux City, Iowa.....	50,000	Driven wells.....	.....	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	No water from the Missouri River used; water supply for twenty years or more practically all from driven wells. According to information from the mayor there occurred in the city within the six months ending April 1, 1910, only 2 cases of typhoid fever, and within the year ending on that date not more than a dozen cases.

Lincoln, Nebr.	65,000	Artesian wells.	January	....	....	1	....	....	1	....	....	....	....	....	....	Water supply practically all from artesian wells; very few private wells in use in recent years. The low typhoid rate, particularly for January, February, and March, 1910, is striking.
			February	....	....	....	....	1	....	1	....	1	....	....	....		
			March	....	....	2	....	....	....	....	....	2	2	1	....		
			April	....	....	1	1	....	....	....	....	....	....	....	....		
			May	....	....	3	....	....	....	1	....	....	....	....	....		
			June	....	....	....	1	....	1	....	1	....	....	....	....		
			July	....	....	2	....	2	....	....	1	....	....	....	....		
			August	4	1	....	....	2	4	....	1	....	1	....	....		
			September	....	5	4	2	4	4	5	1	4	....	....	....		
			October	13	2	....	....	8	....	2	....	1	....	....	....		
			November	2	1	1	....	1	....	....	....	3	1	....	....		
			December	1	....	....	3	....	....	....	....	2	....	....	....		
Total				20	9	14	7	18	10	9	4	13	4	....	....		
Benson, Nebr.	1,500	Artesian wells		(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	This town is practically continuous with the northwest part of Omaha. According to information from local physicians, no cases of typhoid fever developed among the residents of Benson during the four months ending April 1, 1910. In April 2 cases occurred, both in persons who made frequent visits to Omaha.

[a] Records incomplete.

[b] No record.

From the data in this table it appears that the disease in the winter of 1909–10 had an especially high prevalence in those towns and cities which used the insufficiently purified Missouri River water, but not, so far as could be ascertained, in those which used other water. This fact alone points strongly to the Missouri River as the source of the infection which caused the outbreak in Omaha, and suggests that during the winter of 1909–10 the germs of typhoid fever existed in the water of the Missouri River for a considerable part of its course either in unusually large numbers or with an unusually high degree of infectiveness.

That the past winter was an unusually favorable one for typhoid infection in river waters somewhat generally is suggested by the fact that in the extensive territory to the north and east of Omaha a number of cities using water supplies from rivers other than the Missouri had pronounced outbreaks—Minneapolis,[a] Minn., using water from the Mississippi River, and Montreal,[b] Canada, using water from the St. Lawrence River, being striking examples.

CONCLUSIONS.

Prevalence.—In the period from November 25, 1909, to March 25, 1910, typhoid fever prevailed in Omaha in epidemic form. The rate of occurrence during this period was 1 case to about every 225 inhabitants, and, so far as the records show, was over six times as high as the average rate for corresponding periods of previous years.

Age.—The disease was distributed quite generally through the population. Persons between 10 and 30 years of age furnished the majority of the cases. The disease was not especially prevalent among children.

Geographical distribution.—The disease was generally distributed over the city. The rate of prevalence was, so far as could be ascertained, somewhat higher among persons whose residences were connected with the city water, supplied from the Missouri River, than among those whose residences were supplied from other sources, and was particularly high among persons habitually exposed to conditions in an eastern section of the city in which practically all of the water from the Burt street station was distributed.

Diagnosis.—The evidence is convincing that at least 85 or 90 per cent of the cases reported as typhoid fever during the outbreak were correctly reported as such, and that the number of actual cases not reported was fully as large as the number reported as typhoid fever under erroneous diagnoses.

Imported cases.—Not over 5 per cent of the persons affected contracted the infection while away from the city of Omaha. This

[a] Engineering News, 1910, vol. 63, No. 14, April 7, p. 392. [b] Loc. cit.

number was probably more than offset by the number of cases in persons who contracted the infection in Omaha and developed the disease elsewhere.

Ice.—Very few of the persons affected during the period of the outbreak gave a history of having used ice in foods or beverages during the thirty days prior to onset of illness, and ice may therefore be eliminated as having been a considerable factor in the production of the outbreak. But as a considerable proportion of the ice to be used in Omaha during the summer is that which was harvested from the river and other polluted water, this ice may become, upon the advent of warm weather and the consequent increased use of ice in foods and beverages, an important source of infection.

Milk and ice cream.—The evidence is convincing that milk, ice cream, and other dairy products were not a considerable factor in the production of the outbreak.

Raw shellfish.—As only a small proportion of the cases gave a history of having eaten raw oysters or clams within the thirty days prior to onset of illness, these shellfish could have played but a small part, if any, in the spread of the infection.

Raw vegetables.—The evidence is convincing that neither lettuce nor celery could have played a major part in the production of the outbreak.

Bakery products and other general food supplies.—In view of all the evidence, it is not reasonable to believe that bakery products and other general food supplies played more than a secondary and relatively small part in the production of the outbreak.

Dust.—In view of the fact that the ground at Omaha was covered with snow during the greater part of the period in which the outbreak was caused and in view of the general epidemiologic features of the outbreak, it is not reasonably conceivable that such an outbreak could have been caused by infection disseminated in air-borne dust.

Sewage disposal and general sanitary conditions.—As the majority of the cases investigated were found to be among persons living at residences connected with the city sewerage system and at which the general sanitary conditions were good or fairly good, it appears that whatever factors were concerned in the production of the outbreak were not dependent for their operation upon insanitary conditions at place of residence of persons affected.

Contact.—About 13 per cent of the cases investigated gave a history of association during the thirty days prior to onset of illness with previous cases in the febrile stage of the disease and were attributable to infection by personal contact. It appears, therefore, that in Omaha, as is generally true for other places where typhoid fever prevails, personal contact was an important factor in the spread of the infection, but the evidence is abundant and convincing that in this

outbreak personal contact operated as a factor secondary to some other factor which was chief and primary.

Water.—The unusually high rate of prevalence—or outbreak—of typhoid fever in Omaha during the period extending from about November 25, 1909, to about March 25, 1910, was beyond reasonable doubt caused by infection in the water supply obtained from the Missouri River. Some of the points in the evidence on which this conclusion is based are as follows:

(*a*) The river water obtained at both intakes was polluted to a dangerous extent with sewage.

(*b*) The results of the bacteriologic examinations show that during the period in which the outbreak was caused the treatment of the water, previous to its distribution to the city, by storage and by the use of a coagulant was not efficient to render this water reasonably free from dangerous pollution.

(*c*) The vast majority, over 95 per cent of the 103 cases particularly investigated, were in persons who during the thirty days prior to onset of illness used as the sole, principal, or occasional source of water for drinking purposes the unboiled and unfiltered tap water as supplied from the river through the city water system, and besides this water there was no factor common to the majority of the cases which could reasonably be considered as having been concerned in the production of the disease.

(*d*) There was a parallelism between the occurrence of certain unusual climatic conditions which particularly affected the river water and the unusual prevalence of typhoid fever, which very strongly suggests a relationship of cause and effect.

(*e*) Reports from a number of other cities for the period in which the outbreak at Omaha occurred showed that in those cities which were using water from the Missouri River the typhoid fever rates generally were unusually high, while in cities neighboring these but using water from other sources such as wells, springs, lakes, etc., the typhoid fever rates generally were not unusually high.

(*f*) Among persons who habitually used for drinking the water distributed from the Burt street station—which water in the winter of 1909–10 was exposed to greater sewage pollution than it had been in any other winter for certainly many previous years and to relatively more sewage pollution from near-by sources than was the water distributed from the Florence intake—the disease appeared to prevail at a rate which was disproportionately high.

(*g*) The time of occurrence and the extent of the outbreak point to the water supply as the source of the infection.

(*h*) The results of the investigation eliminate, beyond reasonable doubt, all possible sources of infection other than the water supply which could have been responsible for an outbreak of such character.

RECOMMENDATIONS.

1. *The improvement of the water supply obtained from the Missouri River.*—Of the measures required to make this water reasonably free from dangerous pollution, the following are indicated:

(*a*) The abandonment of the intake at the Burt street station as soon as practicable. This is particularly advisable, even if the water supply is to be subjected to purification processes much more efficient than those which have been and are now in operation, because the water at this intake is polluted not only with sewage in the river from more distant sources, but also with the sewage from Florence and from a northwest section of the city of Omaha, having a population of several thousand, and at times of high water with the contents of privies located within a few hundred feet of the intake. There is also contamination of the water at this point by drainage from the dumping ground of Council Bluffs, Iowa, on the east side of the river. None of the processes usually adopted as practicable for the improvement on a large scale of polluted surface river water should be relied upon to remove absolutely all disease-producing organisms. Therefore the water to be treated should be protected as thoroughly as practicable from pollution, particularly near-by pollution, with sewage. If it is not practicable to abandon the intake at the Burt street station, measures should be taken to prevent dangerous pollution of the river between the Burt street and the Florence intakes. Among the measures necessary to accomplish this would be the changing of the course of the Omaha and the Florence sewers so that their sewage would not empty into the river above the Burt street intake.

(*b*) The protection of the Florence intake from pollution entering the river through Mill Creek. This could be accomplished either by moving the intake to a point above the mouth of the creek or by changing the course of the creek so that it would empty below the intake. If it is not feasible at present to secure protection of the water at the Florence intake against the contents of Mill Creek by changing the present relative positions of the creek's mouth and the intake, a considerable safeguard could be accomplished by proper disposal of the sewage on the watershed of the creek for 2 or 3 miles upstream, so that the contents of privies and cesspools would not empty or drain into the creek.

(*c*) The treatment of the water supply by some purification process or processes which will render it free from dangerous pollution. Judging from an inspection of the watershed on each side of the river for a distance of about 10 miles above Florence and from reports as to amounts of sewage entering the river at points farther north, it appears probable that water taken from the Missouri River at any point between 200 and 1,000 feet north of (or upstream from) the

present mouth of Mill Creek would average little, if any, higher in content of disease-producing organisms than would the water taken from the river at any points north of Omaha and south of Sioux City. The self-purification of a river of the character of and being polluted as is the Missouri should not be depended upon. This is particularly true in the time of thaws, when floating ice may carry for long distances organisms, which when so carried are not exposed to the same conditions of sedimentation, etc., as when free in the flowing water. Therefore if the Missouri River is to be continued as the source of water supply for the city of Omaha, this water should be treated in such a way as to make it at all times wholesome and safe before it is delivered to the city.

In this connection the contemplated application to the water of the hypochlorite of lime treatment is to be commended as a step in the right direction. If it be found that the hypochlorite treatment will not effect an improvement to a point which may reasonably be considered one of safety, other processes of purification in the place of or in addition to the hypochlorite treatment should be applied. The efficiency of the hypochlorite treatment should be determined by a thorough bacteriologic study of the water before and after treatment.

The other processes recommended for consideration are (1) increased storage by installation of additional sedimentation reservoirs and (2) filtration.

What processes are best suited to meet the local conditions can be definitely determined only by experimentation. It is suggested that steps be taken as soon as possible to have such experiments conducted under the supervision of persons skilled in engineering and in the bacteriologic and chemical examination of water. On general principles and from such detailed study as has been made, a combination of the following processes for the improvement of the water supply of Omaha is recommended for particular consideration:

(1) Protection, as thorough as may be practicable, of the watershed of the Missouri River against sewage pollution from sources—particularly near-by sources—upstream from the intakes.
(2) Installation of additional storage reservoirs.
(3) Use of adequate amount of coagulant.
(4) Mechanical filtration.
(5) Treatment of effluent from filters with hypochlorite of lime.

(*d*) Until some method or combination of methods of demonstrated efficiency for the purification of the water supply is in operation, the boiling by the people generally of all river water to be used for drinking purposes, or in any other way liable to result in swallowing by persons of organisms contained in the water. The boiling of the water for use in public schools and other public institutions is particularly advisable.

2. *Ice.*—The adoption of measures which will prevent, so far as practicable, the use of natural ice collected from the Missouri River or other polluted sources in drinking water or any foods or beverages subsequently to be consumed without cooking.

3. *Cesspools and privies.*—The immediate abolishment of all faulty cesspools and privies. All cesspools and privies should be abolished as rapidly as the extension of the sewerage system will permit. On premises not having sewer connections, cesspools which are not known to be water-tight, and which are not so maintained as to obviate any reasonable likelihood of leakage of contents occurring, with resulting pollution of surroundings, should be replaced with privies having water-tight tubs, pails, or boxes, placed above ground, for the reception of sewage. The privies should be screened so that flies will be prevented from having access to the contents. The tubs or boxes should be emptied before they become more than two-thirds full of sewage. The use of an efficient germicide, such as a solution of carbolic acid or chloride of lime, so as to keep the privy contents disinfected, is advisable at all times, and particularly in the summer time. The disposal of the privy contents through septic tanks connected with the sewerage system is suggested. All cesspools, whether to be maintained or abolished, should be disinfected as thoroughly as possible. This is particularly indicated for those which have received the dejecta from typhoid-fever patients.

4. *The exercise of rigid precautions at the bedside to prevent the spread of infection from typhoid-fever patients.*—As soon as a case is reported a representative of the health office should visit the residence of the patient and make an investigation to determine if possible how the infection was contracted and to see that the proper precautions are being exercised to prevent the spread of infection from the patient. The employment of visiting nurses to aid in the carrying out of precautionary measures at homes of typhoid-fever patients is strongly advised. Provision should be made for the free distribution of disinfectants to families unable to purchase them.

5. *The improving of general sanitary conditions and the exercise of as rigid sanitary supervision as possible over all places where foods or beverages are prepared for sale or offered for sale.*—These general sanitary measures are, of course, always advisable, but they are particularly so in Omaha at the present time, when the city has just passed through an extensive outbreak of typhoid fever and has, in consequence, an unusually large number of foci of infection in typhoid-fever patients and probably in typhoid-bacillus carriers, and with the warm weather season approaching, when the conditions are usually most favorable for the spread of prosodemic typhoid fever.

APPENDIX.

An ordinance relating to the water supply of Omaha, passed April 26, 1910, and approved April 28, 1910:

ORDINANCE No. 7113.

An ordinance providing for the preservation of the public health of the residents of the city of Omaha, to prevent disease, to guard against epidemics of disease, to fix a standard of purity and quality of water brought in the city through pipes or other means and delivered, sold, or distributed to the residents thereof to be used for drinking, household, or domestic purposes, and of all water so used or intended to be used in said city.

Be it ordained by the city council of the city of Omaha:

SECTION 1. That on and after thirty days from the passage and approval of this ordinance all water furnished or offered for sale or sold in the city of Omaha for drinking, household, or domestic uses and pusposes and all water brought into the city through pipes or otherwise for such purposes and uses and so offered for sale, delivery, or distribution by any person, firm, company, or corporation shall be of the standard of purity, both chemical and bacteriological, as follows: It shall not contain more than one hundred bacteria per cubic centimeter, examined according to the standard methods adopted by the American Public Health Association, and shall exhibit fermentation in not more than thirty per cent examined when ten cubic centimeters or less of water is used in such examinations, standard lactose bouillon being the medium used.

The chemical water factors must never exceed the following proportions:

	Parts per million.
Total solids	500.00
Free ammonia	.06
Albuminoid ammonia	.08
Oxygen absorbed in ten minutes at 100° C	3.00
Nitrogen as nitrites	None.

Provided, That after fifteen months from the approval of this ordinance all water shall be of the standard of purity, both chemical and bacteriological, as follows, to wit: It shall be free from any gas-producing bacteria, colon bacilli, or other pathogenic bacteria. The number of bacilli must not exceed fifty per cubic centimeter. The chemical water factors must never exceed the following proportions:

	Parts per million.
Total solids	475.00
Free ammonia	.04
Albuminoid ammonia	.05
Oxygen absorbed in ten minutes at 100° C	2.00
Nitrogen as nitrites	None.

And water must be clear without suspended matter.

No person, firm, company, or corporation shall hereafter furnish for sale, or sell, deliver, offer to deliver, or distribute in the city of Omaha any water or waters for drinking, household, or domestic purposes that is not of the standard of purity, both chemical and bacteriological, hereinabove required.

SEC. 2. The commissioner of health of the city of Omaha shall have the right to inspect any and all reservoirs, tanks, or other receptacles from which water is furnished to the residents of the city and to inspect any and all intakes, pumping stations, water plants, and all bodies of water from which any portion of the supply of water for the city is obtained for the purpose of making such tests and examinations as he may deem necessary for the protection of the public health; and he shall require a bacteriological and chemical test of the water from any water plant or system and all reservoirs from which water is furnished, sold, or distributed to the residents of the city at least once each month, and such report in detail shall be submitted to the mayor and city council. And the commissioner of health may cause to be made whenever he may see fit an examination of any and all water from any source sold, delivered, furnished, used, existing, or kept within the city for drinking or other domestic purposes, including the water from any well within the city, to determine the standard of purity of such water.

SEC. 3. For all purposes and in any suit in court where the provisions of this ordinance or the quality of the water provided for herein may be material or involved, whether on account of violations of the provisions of this ordinance or otherwise, all tests made by the bacteriologist or chemist appointed by the commissioner of health of the city of Omaha of water furnished, sold, distributed, or offered for sale to consumers within the city by any firm, person, company, or corporation, when certified to or supported by the oath of such bacteriologist or chemist employed, appointed, or otherwise authorized by the commissioner of health shall be deemed and accepted as prima facie correct, and all instruments used by said bacteriologist or chemist in making such tests, where such tests are made, shall for all such purposes be deemed and held to be prima facie correct.

SEC. 4. If any person, firm, company, or corporation shall furnish to consumers within the city of Omaha for drinking or other domestic or household purposes water below the standard of purity required by this ordinance such person, firm, company, or corporation shall forfeit and pay to the city of Omaha for such violation of this ordinance the sum of one thousand dollars ($1,000) per week for each and every week during which such person, firm, company, or corporation shall violate the provisions of this ordinance by furnishing to the residents of the city of Omaha and selling or offering for sale and distribution for drinking or other household or domestic purposes water below the standard of purity herein required, and said amount may be recovered in a civil action in any court at law having jurisdiction thereof: *Provided*, That the city of Omaha shall, through its mayor and council, deduct from any amount due to any firm, person, company, or corporation engaged in supplying water to the residents of the city of Omaha in said city an amount equal to all sums which by the terms of this ordinance have been forfeited to the city by reason of a violation of the terms and provisions hereof; and before any appropriation shall be made by the mayor and council in favor of any such person, firm, company, or corporation for any purpose the amount so forfeited to the city under the provisions of this ordinance shall be deducted by the comptroller from the amount due any such person, firm, company, or corporation under contract or otherwise.

SEC. 5. In case any person, firm, company, or corporation shall, after receiving notice of the result of any test as provided for herein, continue to furnish, sell, distribute, or offer for sale and distribution to the residents of the city of Omaha water below the standard of purity fixed by this ordinance such person, firm, company, or corporation and the managing officers and agents thereof shall be deemed guilty of a misdemeanor and upon conviction thereof shall be punished by a fine of not more

than one hundred dollars ($100) or by imprisonment for a term not exceeding ninety days in jail, and each day that such person, firm, company, or corporation shall so continue to furnish, sell, or distribute to the residents of the city of Omaha for drinking, household, or other domestic purposes water below the standard of purity fixed by the terms of this ordinance shall be deemed a separate offense and punishable as such.

SEC. 6. This ordinance shall take effect and be in force from and after its passage.

LOUIS BURMESTER,
President City Council.
DAN B. BUTLER,
City Clerk.

Passed April 26, 1910; approved April 28, 1910.

JAMES C. DAHLMAN,
Mayor.

II. THE WATER SUPPLY OF WILLIAMSON, W. VA., AND ITS RELATION TO AN EPIDEMIC OF TYPHOID FEVER.

II. THE WATER SUPPLY OF WILLIAMSON, W. VA., AND ITS RELATION TO AN EPIDEMIC OF TYPHOID FEVER.[a]

By W. H. Frost,

Passed Assistant Surgeon, United States Public Health and Marine-Hospital Service.

INTRODUCTION.

The excessive prevalence of typhoid fever in the town of Williamson, W. Va., during the fall and winter of 1909–10 aroused the citizens of the town to a realization of the ever increasing danger from their present water supply, which is derived from the Tug Fork Branch of the Big Sandy River. Accordingly a bond issue was voted for improvement of the public water supply and other municipal improvements; and a request made through the West Virginia state board of health to the Surgeon-General of the Public Health and Marine-Hospital Service to detail an officer for the purpose of making an investigation and giving advice as to the best means of so purifying the town's water supply as to prevent typhoid fever.

In response to this request the writer was directed to proceed to Williamson, confer with the representatives of the state board of health and make such investigation as might be required.

On arrival at Williamson a conference was held with Dr. H. A. Barbee, secretary and executive officer of the West Virginia state board of health, and Dr. Tunis Nunemaker, health officer of Williamson, and a brief preliminary survey of the situation made in their company.

It was ascertained that the town had suffered during the winter of 1909–10 from a serious outbreak of typhoid fever, which was generally ascribed to the use of water from Tug River, the pollution of this stream being so gross that its danger as a source of drinking water was evident to the most casual observer. Even a brief survey of the town, however, showed conditions other than pollution of the water supply which must necessarily be favorable to the spread of typhoid fever, and it was evident that for a successful campaign against typhoid fever these factors must be appreciated, the experience of many cities, especially in the southern section of the United

[a] Manuscript submitted for publication August 19, 1910.

States, having shown that the reduction in the typhoid rate following an improvement in water supply without a coincident campaign against other factors in the spread of the disease is often, if not usually, disappointing It was determined, therefore, while the laboratory investigation of the water supply was in progress, to devote such time as could be spared from this work to a field study of typhoid fever in Williamson, to determine its prevalence and causes.

The investigation, begun May 27, 1910, and continued until June 18, included:

(1) A study of sanitary conditions in general at Williamson.

(2) A study of the water supply of the town and of Tug River, with the object of ascertaining the degree of pollution and the available means of purification.

(3) The collection of data concerning the cases of typhoid fever occurring in Williamson since November 1, 1909.

(4) An investigation of the acute diarrhea, locally prevalent.

The necessary laboratory outfit was supplied from the Hygienic Laboratory; and a temporary laboratory established in Williamson.

Upon completion of the investigation a verbal report was made to the town council and board of health, and a written report with recommendations, forwarded to the Surgeon-General, Public Health and Marine-Hospital Service, embodying in slightly briefer form the substance of this report.

It is a pleasure to acknowledge my indebtness for cooperation and assistance in this investigation, to Dr. H. A. Barbee, secretary and executive officer of the state board of health, to Dr. Tunis Nunemaker, health officer of Williamson, to Mr. Alonzo Pinson, mayor of Williamson, to the members of the town council and board of health, and to many other citizens of Williamson. I am especially indebted to Doctor Nunemaker for the devotion of much of his time to assisting in the investigation. The courtesy of the medical profession of Williamson and vicinity in supplying information and opportunities for clinical studies is gratefully acknowledged. To the Norfolk and Western Railway Company, especially Mr. W. H. Lewis, superintendent of motive power, Mr. James H. Gibbony, chief chemist, and Mr. D. G. Cunningham, superintendent of machinery and repairs at the Williamson yards, I am indebted for their cooperation and for information which would not have been available from other sources.

TOPOGRAPHY AND GENERAL SANITARY CONDITIONS.

Williamson, the county seat of Mingo County, W. Va., is situated on the east bank of the Tug Fork of the Big Sandy River, on the southwestern border of the State. It is a thriving town whose present population is locally estimated at between 4,000 and 5,000

inhabitants. Its growth has been very rapid, the population in 1900 having been only about 600.

The town is situated on the main line of the Norfolk and Western Railway, and is the terminus of a division of this road. The Norfolk and Western Railway Company has here a large yard, which furnishes employment to a considerable proportion of the population. East Williamson, the section of the town adjacent to the Norfolk and Western Railway Company's yard, is made up almost entirely of this company's employees and their families.

Although situated in a productive portion of the Tug River coal fields, Williamson is not properly a mining town; there are, however, two coal mines in operation within the town limits, both situated upon a small stream which empties into Tug River below East Williamson, and just above the main portion of the town. The population on the upper portion of this branch is largely composed of employees of the larger of these two mines above mentioned, operated by the Williamson Coal Company.

Williamson is fairly distinctly divided into three sections. The larger portion of the town, comprising the business section and the better residences, is situated below the Williamson Branch, on a tract of flat ground, rising on all sides in steep slopes, forming a kind of amphitheater. The Williamson Branch section of the town, a narrow row of houses along the banks of this small stream, is separated from the main portion of the town by a high ridge. At the head of this branch is the Williamson Coal Company's mine and a settlement of employees and their families. East Williamson, separated from this section by a second ridge, extends east, parallel to the river, from which it is separated by the Norfolk and Western Railway Company's yard. Williamson proper and East Williamson are shown on the accompanying map. The settlement at the Williamson Coal Company's mine is not shown on this map, being located above the upper margin.

The town is at present only partially provided with a closed sewer system, consisting of a 41-inch brick main, and smaller branch sewers of tiling. This system, constructed in 1907, and gradually extended since that time, connects now only with the main portion of the town, and some sections of even this portion of the town are still without sewer connections, notably some outlying blocks and many of the houses which are situated directly upon the river bank. The main sewer terminates in an open ravine about 100 yards distant from the river, and through this ravine empties into Tug River about opposite the center of the town below the intake for the water supply. There are several criticisms to be made of this sewer system. It is not sufficiently extensive. It is in many places in bad repair. It is designed as a combined system, but is of insufficient capacity to carry

off the large volume of surface water following a heavy rain, with the result that flooding is by no means infrequent. The termination of the closed sewer in an open ravine more than 100 yards from the river is highly objectionable.

The Williamson Branch section of the town has no closed sewer system. Some of the houses on the lower portion of this branch have sewers which empty directly into the stream. Their openings are often high in the bed of the stream, far above the average water level. The remainder of the houses in this section are provided with open privies of the most insanitary kind as regards construction, location, and care. The privies are practically all within 100 yards of the stream and within less than that distance of their respective houses. They are almost invariably situated above the houses to which they belong, often on sharply sloping ground. Every rain must wash a large portion of the contents of these privies through the yards of the residences and into the stream, which thus becomes an open sewer. This stream, usually of small volume, in its passage down to the river several times crosses the street, is at all times in close proximity to the houses along this street, and often passes through yards within a few feet of residences or even directly under them. In dry seasons the stream goes dry, at which times the volume of sewage being insufficient to flow through the bed of the stream must accumulate there. This stream empties into Tug River about 200 yards above the present intake for the town water supply and upon the same side of the river. The water of Williamson Branch, being extremely black from coal washings, forms a marked contrast with the water of Tug River at times when the latter is laden with clay, and at such times it can readily be observed that the water from Williamson Branch passes over the town's intake before becoming thoroughly mixed with the water of the river.

The third section of the town, East Williamson, with the exception of the large Y. M. C. A. building, has no sewers. The houses in this section of the town are provided with open privies, very rarely with cesspools. The privies are invariably situated within a few yards of the residences—often less than 20 feet from a kitchen—and in a large proportion of cases are on a hillside above the houses. They are open privies, badly cared for, and at this season swarming with flies. The Y. M. C. A. building in East Williamson, which receives the sewage from 100 to 200 persons, has a private sewer emptying into the river above the opening of the Williamson Branch. The surface washings of the whole of East Williamson are carried into the river within a mile above the intake for the city water supply.

Upon request, the board of health of Williamson authorized a sanitary survey of the town under the direction of the health officer. This survey, owing to several unfavorable circumstances, had not

been completed at the time of my departure, but from a compilation of the inspection reports from ten representative blocks of the main portion of the town, the following figures were obtained:

	Number.
Residences inspected	105
Residences having water-closets	79
Residences having open privies	33
Residences in good sanitary condition	33
Residences in fair sanitary condition	40
Residences in bad sanitary condition	32
Occupants in above residences	544
Occupants using city water for drinking	367
Occupants using well water for drinking	130
Occupants using safe (deep well, boiled, distilled) water for drinking	47

These blocks include some of the poorest as well as some of the best of the main section of the town. All of these premises are within a short distance of sewers, yet nearly one-third have open privies. Almost one-third of the residences are reported as in bad sanitary condition, while more than a third are reported as in "fair" condition. Taking into consideration the fact, omitted in these reports, that premises otherwise in the best of sanitary condition are often rendered dangerously insanitary by proximity to other premises in bad condition, it is safe to assume that fully one-half of these residences are, by reason of neglect or location, in a bad, really dangerous sanitary condition.

WATER SUPPLY.

The water supply of Williamson is obtained from Tug River. Water is pumped from the river to all sections of the town. East Williamson, however, has been thus supplied only since the summer of 1909.

The Tug Fork branch of the Big Sandy River rises in the eastern part of McDowell County, W. Va., and, flowing in a general northwest direction, joins the Louisa Fork at Louisa, below Williamson, to form the Big Sandy River. Above Williamson this river drains practically all McDowell County, W. Va., and the western portions of Wyoming and Mingo counties, W. Va., Tazewell and Buchanan counties, Va., and Pike County, Ky. This watershed is mountainous, with very steeply sloping ridges, generally wooded, for the most part sparsely inhabited, little cultivated, and but little used for grazing.

In the absence of any hydrographic data, no definite statement can be made as to the area of this water-shed and the volume and discharge of this river. It is evident, however, from the contour of the country and from local information that the volume of the river is subject to extreme fluctuations. Following heavy rains its rise is very rapid and extreme, while in dry seasons it is said to become so

small that one can cross it dry-shod at Williamson; and its tributary streams at such seasons are often completely dry. The flow of the river is very rapid. Except after heavy rainfalls its water is naturally fairly clear, but in this respect, as in volume, it shows great and sudden variations. The large amount of coal dust discharged into the stream throughout its course gives it a very dark color and adds considerably to its turbidity. A deposit of coal dust in the river bed adds to the apparent dark color of the water, giving it an extremely dirty and displeasing appearance.

The population on this watershed has increased so rapidly within the last ten years that no approximate estimate can be given of it. It is probable that the number of inhabitants per square mile is very small as compared with the watershed of many rivers whose waters are used for municipal supplies; but even if the population per square mile could be stated it would be misleading in an estimation of the pollution, owing to the concentration of population upon the banks of the river and some of its larger tributaries.

The Norfolk and Western Railroad follows Elkhorn Creek from Coaldale, W. Va., to the junction of this creek with Tug River at Welch, W. Va., whence the railroad follows the river closely to a point below Williamson. From Coaldale to Williamson (a distance of about 92 miles) the banks of the river are lined with an almost continuous chain of coal camps and mining towns, varying in population from a few score to 4,000 or 5,000. In these towns the population is almost invariably spread out along the banks of the river or one of its tributaries, probably 90 per cent of the population being within 200 yards of these streams. Welch, at the mouth of Elkhorn Creek, Matewan, at the mouth of Mate Creek (about 9 miles above Williamson) and very probably other towns along the river have closed sewers discharging into Tug River. In the smaller towns and coal camps, however, open privies are in general use. These are situated almost invariably near and often overhanging the stream, so that heavy rains must invariably wash a large part of their contents directly into the stream. Hogpens, mulepens, and stables are very commonly seen immediately upon the banks of the river. Add to this the garbage from hundreds of squalid back yards on the river banks and the refuse from scores of coal mines, all going into this small stream, and the result is a pollution peculiarly offensive to the eye and dangerous to health. Lewis, in a publication of the Geological Survey, in 1906,[a] says of this river:

> Tug Fork of the Big Sandy * * * probably carries more offensive pollution than any stream in West Virginia, which is saying a great deal.

[a] Lewis, Samuel James, Quality of water in the upper Ohio River Basin and at Erie, Pa., U. S. Geological Survey, Water Supply and Irrigation Paper, No. 161, 1906, p. 101.

Since 1906 the population on the banks of the river has increased very considerably, with a corresponding increase in the pollution of the stream.

Several factors add to the dangerous nature of the pollution of Tug River. The sudden rise and rapid run-off after rains wash into the river the filth which has accumulated upon its banks. On the other hand, the small volume of the river in dry seasons increases the concentration of such sewage as gets into it. Whether the degree of pollution is greater at high or at low stages of the river could be determined only by investigation, and would depend, of course, on various factors. The rapid flow of the river decreases the natural purification by sedimentation and diminishes the effect of unfavorable environment upon pathogenic organisms by decreasing the time during which they must be exposed to such environment. From such reports as were available, typhoid fever seems to be excessively prevalent along the river, and the insanitary condition of the residences certainly warrants the inference that careful disinfection of typhoid excreta is by no means universal.

The coal dust which finds its way into the stream and which adds so greatly to its appearance of pollution can not be considered as rendering the water more dangerous for drinking, although it certainly renders it less fit for other domestic purposes, and, by increasing the sulphates, less suitable for use in boilers.

The present intake for the water supply of Williamson, constructed in 1907, consists of a cement caisson, open at the top, 4 feet in depth, sunk below the bed of the river. This caisson is filled with coke, gravel, and sand to a depth of about 4 feet. The intake pipes, passing through this material, open at the bottom of the caisson. The suction of the pumps forces the water through the rough filter bed of the caisson into the intake pipes. When the filter becomes clogged it is cleaned by reversing the pumps. This has to be done at intervals varying from two to twelve hours. While this arrangement removes a considerable part of the coarser suspended matter from the water, it is an extremely crude and inefficient process of filtration, more properly speaking, only a "screening process."

This intake is situated about opposite the central portion of the town, above the outlet of the main sewer, but below the points at which the sewage from Williamson Branch and from East Williamson (aggregating about 1,500 people) enters the river. The water of Williamson Branch, as mentioned above, passes over the intake before being thoroughly diffused into the river, and is therefore especially dangerous.

From the pump house, situated on the bank of the river at the intake, water is distributed directly to the town. A reservoir of about 250,000 gallons capacity is situated beyond and above the

town; this reservoir, however, serves only to receive the surplus of water pumped over water used from the mains, and has no function as a distributing or storage reservoir, serving chiefly as a "safety valve" to equalize the pressure in the mains.

The water supplied is of very displeasing appearance, as is to be expected from the nature of its source and the crudity of the filtration process. It is frequently too black to be fit for bathing and laundry purposes, and often has an offensive odor. The water pipes apparently contain a considerable accumulation of sediment, as it frequently happens that there is a large amount of dirt and coal dust forced out when a tap is first turned on.

Owing to the dangerous and unpleasant character of the city water supply, a considerable proportion of the population of Williamson use other water for drinking purposes. A distilling plant in the town furnishes distilled water to the small number of people who are willing to bear the expense of such a supply. Comparatively little bottled water from distant springs is sold; a few people use water from nearby country springs, usually safe from dangerous pollution. The only deep well of importance in the vicinity furnishing water of good potable quality is one 330 feet deep at the Williamson Coal Company's mines, which supplies the employees at the mine and is piped to the houses in the immediate vicinity, where, however, it is, unfortunately, little used. The well at present in use failed to supply sufficient water during the dry weather of the fall of 1909. A new well 500 feet deep has been bored near by, but not yet put into use.

A very small proportion of people boil the river water before use. From a canvass of over 500 people it was ascertained that less than 10 per cent were at that time using water which might be considered assuredly safe, and it is certain that many of these people were not consistent in the practice.

The town has numerous shallow wells, which are almost without exception subject to gross pollution, but are nevertheless used by a considerable proportion of people on account of the clearness of the water. Probably 20 per cent of the population of the main portion of the town use water from shallow wells.

Water from shallow springs, subject to dangerous pollution, is largely used, especially by the people living on the Williamson Branch. So far as could be ascertained, the majority of the people in East Williamson have been, and still are, in the habit of using well water for drinking purposes. The wells in this section of the town are mostly pipe-lined driven wells, sufficiently deep to be probably safe from pollution.

The Norfolk and Western Railway Company, having been unable to obtain from driven wells sufficient water of suitable quality for

use in their boilers, have constructed an infiltration gallery opposite their roundhouse above Williamson. Perforated brass pipes are laid horizontally several feet below the bed of the river, covered with gravel and sand. The water obtained is fairly clear and is satisfactory for steam purposes, but by no means safe bacteriologically. The company, realizing the importance of a safe water supply, has recently installed a distilling plant to furnish drinking water to the employees in the yard, and allows the men to take home, without charge, sufficient of this water to supply their families.

EXAMINATIONS OF THE WATER SUPPLY.

Bacteriological examinations of water were made at Williamson from May 30 to June 15, 1910, as follows:

	Samples.
Tug River at Williamson intake	7
Water from taps in the town	9
Tug River above Pond Creek	10
Shallow wells	6
Springs	1
Deep wells	3
Infiltration gallery, Norfolk and Western yards	4
	40

Bacterial counts were made from standard agar plates incubated at room temperature from forty-eight to seventy-two hours. A few counts were made from plates incubated at 38° C., but results at this temperature proved less satisfactory than at room temperature.

Tests for *B. coli* were made mostly with lactose bile; gas formation in this medium within forty-eight hours was taken as presumptive evidence of the presence of *B. coli*. In seven instances these presumptive tests were confirmed by plating on lactose-litmus-agar or Endos's medium, obtaining in all these cases plate colonies characteristic of *B. coli*. In a few instances, owing to shortage in supply of lactose bile, lactose bouillon was used in the fermentation tests. In these cases gas formation within twenty-four hours was considered presumptive evidence of the presence of *B. coli*.

Additional quantitative estimations of *B. coli* were made by a plate method advocated by Marmann,[a] which, with slight modification, has been used with very satisfactory results in the Hygienic Laboratory. One cubic centimeter of water was spread upon a plate of Endos's fuchsinagar, the plate placed uncovered in the incubator until dry, then covered, incubated fourteen to twenty-four hours, and the red colonlike colonies counted. Control plates with sterile water showed no growth.

[a] Marmann Centralbl. f. Bakt. etc., I Abt., Orig., 1909, Bd. 50, pp. 267–282.

The following tables give in detail the results of turbidity readings and bacteriological examinations of water made at Williamson:

TABLE NO. 1.—*Water from Tug River above Williamson.*

Date.	Turbidity.	Bacteria per c. c. agar (48–72 hours).	B. coli (presumptive) present in—	
			0.1 c. c.	1 c. c.
1910.				
May 30	(a)	420	+	+
May 31	(a)	1,900	+	+
June 1	20	380	+	+
June 2	20	310	+	+
June 3	15	480	−	+
June 4	15	145	+	+
June 6	200	6,100	+	+
June 7	200	10,000	+	+
June 8	160	5,200	+	+
June 13	(?)	4,200	+	+

a Turbid.

TABLE NO. 2.—*Water from Tug River at Williamson intake.*

Date.	Turbidity.	Bacteria per c. c. agar (48–72 hours).	B. coli (presumptive) present in—	
			0.1 c. c.	1 c. c.
1910.				
May 30	(?)	1,450	+	+
June 2	20	1,075	+	+
June 4	20	3,600	+	+
June 6	130	9,200	+	+
June 7	200	10,000	+	+
June 10	50	3,000	+	+

TABLE NO. 3.—*Water from taps in Williamson.*

Date.	Turbidity.	Bacteria per c. c. agar (48–72 hours).	B. coli (presumptive) present in—	
			0.1 c. c.	1 c. c.
1910.				
May 30		530	+	+
June 1		600	+	+
June 2	20	480	+	+
June 3	18	1,200	+	+
June 4	10	1,170	+	+
June 6	15	690	+	+
June 7	25	1,400	+	+
June 8	35	1,600	+	+
June 10	10+	550	+	+

TABLE NO. 4.—*Water from pump (infiltration gallery).*

Date.	Turbidity.	Bacteria per c. c.	B. coli (presumptive) present in—	
			0.1 c. c.	1 c. c.
1910.				
June 1	8	150	−	+
June 3	10	100	−	+
June 6	18	1,800	+	+
June 13	(?)	710	+	+

TABLE NO. 5.—*Water from wells and springs in Williamson.*

Date.	Source.	Turbidity.	Bacteria per c. c.	B. coli (presumptive) present in—		
				0.1 c. c.	1 c. c.	10 c. c.
1910.						
May 31	230-foot driven well (W. C. C.)	Turbid.	34	.....	−	+
June 9	.....do	Clear.	40	.....	−	−
June 4	Driven well (J. K. A.)	...do	58	.....	+(?)	+(?)
June 3	Shallow dug well (J. R.)	...do	700	+	+	+
June 10	Shallow dug well, tile-lined (G. R. C.) [a]	...do	1,000	.....	+	+
June 14	Shallow well, tile-lined	...do	4	−	−	−
June 14	Surface spring	...do	80	−	−	+
June 15	Shallow well (W. C. C.) [b]	...do	(c)	.....	+	.....
June 15	Shallow well (A. B.) [d]	...do	(c)	.....	+	.....

[a] B. coli on Endo plate=20 per c. c.
[b] B. coli=25 per c. c.
[c] No count.
[d] B. coli=15 per c. c.

TABLE NO. 6.—*Summary of the results of the examinations of Tug River water.*

Source of samples.	Number of samples examined.	Average number of bacteria per c. c.	Percentage of samples showing B. coli in—			Number of B. coli per c. c. as estimated by plate method (Endo's medium).
			0.1 c. c.	1 c. c.	10 c. c.	
Tug River above Williamson	10	2,900	90	100	.....	.....
Tug River at Williamson intake	7	4,700	100	100	.....	[a] 50+
Taps in Williamson	9	895	100	100	.....	[a] 16
Tap at Norfolk and Western pump house	4	690	50	100	.....	.....

[a] Two samples.

From these figures it is seen—

(1) That Tug River, even above Williamson, is highly polluted, 90 per cent of 0.1 c. c. samples and 100 per cent of 1 c. c. samples showing the presence of *B. coli*, indicating an average number of at least 9 *B. coli* per c. c. for the samples examined.

2. That the water at the Williamson intake is very considerably more polluted than at a point above the town, showing a bacterial count almost twice as high, with *B. coli* constantly present in 0.1 c. c. Quantitative estimations of *B. coli* on two occasions indicated that 50 *B. coli* per c. c.—an extreme pollution—is not an excessive estimate.

3. That the present intake filter, though considerably decreasing the turbidity and removing a considerable proportion of bacteria from the water, is altogether inadequate as a means of purification.

4. That the Norfolk and Western Railway Company's well, situated below the bed of the river above Williamson, gives an effluent of considerably better quality, but that this water is still very far from being bacteriologically safe.

5. Of the six shallow wells examined, five were found to be grossly polluted; one showed no evidence of pollution. This is probably accounted for by the fact that the bottom of this well is in a very dense layer of clay, probably impervious, and that the well is tile lined to the bottom.

6. The two deep wells examined both showed doubtful evidences of slight pollution at the first examination, these wells having been stagnant for some time previous to the collection of the samples. A second sample from one of these wells proved to be of good quality according to bacteriological standards.

The one spring examined, situated on a hillside outside of the town, showed *B. coli* in 10 c. c., not in 1 c. c. nor 0.1 c. c. This slight pollution was probably due to animal excreta, washed in by recent heavy rains.

The conditions at Williamson from May 30 to June 15, 1910, were unfavorable for obtaining an accurate idea of the variations in bacteriological quality of the water under various conditions. The river during this time was uniformly high and the weather moderately cool, so that no information could be obtained as to the effect of low water and high temperatures on the bacterial content of the water.

From the limited observations which could be made on this point it is inferred that Tug River does not show the constant high turbidity characteristic of many southern and western streams. Following is a summary of the turbidity readings taken:

	Above Williamson.	At Williamson intake.	Taps in Williamson.
1910.			
June 1	20	.....	.....
June 2	20	20	20
June 3	15	.....	18
June 4	15	20	10
June 5	.....	.....	.....
June 6	200	130	15
June 7	200	200	25
June 8	160	.....	35
Average	90	92.5	20.5
Maximum	200	200	35
Minimum	15	20	10

The occasional high turbidity, due to suspended clay, and the usual dark color, indicate the necessity of a coagulant to satisfactorily clarify the water.

Samples were collected June 1, 1910, and sent to the Hygienic Laboratory for chemical examination. Following is an abstract of the report of Passed Asst. Surg. Norman Roberts on the chemical examination of these samples:

	Sample from Tug River.	
	Above Williamson.	At Williamson intake.
Color	Very slight..	Very slight.
Odor	Decided, aromatic.	Faint, aromatic.
	Parts per million.	
Total solids (exclusive of sediment)	71,000	99,000
Loss on ignition	19,000	26,000
Nonvolatile residue	52,000	73,000
Chlorine	1,000	10,000
Nitrogen as—		
Free ammonia	.030	.018
Albuminoid ammonia	.058	.042
Nitrites	.001	.001
Nitrates	.400	.400

PREVALENCE OF TYPHOID FEVER.

There are no records from which information can be gathered as to the number of cases of typhoid fever in Williamson or deaths therefrom in previous years. I was informed that about 1900, when the population of the town was approximately 500, there was an epidemic of more than 60 cases of typhoid fever. This epidemic occurred in the summer and fall. The water supply at the time was from shallow wells and springs, and, it being prior to the construction of a sewerage system, privies were then in general use. The mortality of this epidemic is unknown.

Since 1900 there had been no epidemic of typhoid fever in Williamson until the winter of 1909–10. The disease had, however, been constantly endemic; and while no approximate estimate can be given of the average annual case rate, it must have been excessive. This is inferred from the knowledge that conditions have been favorable for its spread and measures for its prevention extremely lax. The inference is further justified by the large proportion of people in Williamson who give a history of having had typhoid fever, as well as by the general statements of local physicians and others. It is the impression of the physicians in Williamson that there is usually no marked seasonal variation in the prevalence of typhoid fever there, it being about as common at one season as at another.

Prior to January 1, 1910, no attempt had been made to have cases of typhoid fever or even deaths reported; in fact, for some two years prior to that time the town had been without a board of health or a health officer. Since January 1, 1910, physicians have been required to report to the health officer all cases of typhoid fever, but it was ascertained that less than half of the cases diagnosed by the attending physician as typhoid fever had been so reported, and that the death records were equally deficient.

The health officer had on his records reports of some 50 cases of typhoid fever occurring since January 1, 1910; but was certain that there had been many more than this, estimating the number as 125 since November, 1909, about which time typhoid fever commenced to be unusually prevalent.

A request was made of each physician in town to furnish a memorandum of all cases of typhoid fever seen by him since November 1, 1909, giving the address, sex, race, and age of patient, date of onset of symptoms, duration and termination of illness. From these reports, courteously and promptly supplied, it was ascertained that from November 1, 1909, to June 1, 1910, 152 cases had been diagnosed and treated as typhoid fever, with 11 deaths. Two other fatal cases, as to the diagnosis of which some doubt was expressed, may be considered as possibly typhoid fever.

The low death rate (7.29 to 8.5 per cent according as deaths are estimated at 11 or 13) is more remarkable in view of the unfavorable circumstances under which many of the cases had to be treated. It was reported by all the local physicians that a considerable proportion of their cases were of mild type and short duration, some being confined to bed not more than two to three weeks. The low death rate and the number of mild cases suggest that a considerable proportion of the cases may have been paratyphoid infection, this suspicion being strengthened by the reported frequency of onset with gastro-intestinal disturbances. Unfortunately no bacteriological nor serological examinations of any of the cases had been possible. A few blood cultures and Widal tests were made during my stay in Williamson, and since that time Widal tests have been made with two specimens of blood sent to the Hygienic Laboratory by Doctor Nunemaker. In making blood cultures, 5 c. c. of blood, withdrawn from a vein of the forearm, were planted in ox bile, incubated twenty-four hours, at 38° C., then plated out on lactose litmus agar. The organisms isolated have been fully identified at the Hygienic Laboratory by cultural and agglutinating tests.

TABLE No. 7.—*Summary of the results of blood cultures and agglutination tests.*

Patient.	Age.	Duration of illness when specimen was taken.	Result of blood culture.	Agglutination.	Clinical course.
J. E.	50	Second week.	B. typhosus.	Positive 1-40 B. typhosus.	Mild, convalescent within 3 weeks.
A. B.	5	First week.	None made.	do.	Do.
L. S.	26	do.	B. paratyphosus "A."	Negative B. typhosus. 1-40.	Mild, defervescent within 3 weeks.
L. J.	10	do.	Negative.	do.	Mild, short duration.
F. J.	(a)	Fourth week.	None made.	Positive B. typhosus. 1-40.	Severe hemorrhage.
McC.	(a)		do.	do.	Unknown.

a Adult.

Four of the above cases may be considered as satisfactorily demonstrated to be typhoid fever and one paratyphoid, A. In the sixth case (L. J.), where the tests made were negative, the diagnosis is doubtful, but the clinical diagnosis of typhoid fever is justified. It is to be regretted that more clinical and bacteriological studies could not be made, but from the above it is evident that the majority of the cases prevalent in May were true typhoid infections, while paratyphoid infection was also present.

While it is probable that in this, as in all epidemics, there was a certain percentage of error in the clinical diagnosis of typhoid fever, there is no reason to suppose that this error was excessive or more than would be counterbalanced by mild, unrecognized cases.

EXTENT AND DISTRIBUTION OF EPIDEMIC.

The 152 cases of typhoid fever occurring in a population of 5,000 are equivalent to a case rate of 3,040 per 100,000, or one case among every 33 people. An epidemic of only 152 cases can hardly be called extensive; the figures, in fact, are very small as compared, for instance, to the number of cases occurring annually in many large cities where the disease is not epidemic. Considering, however, that one out of every 33 inhabitants of the town was attacked within seven months, the epidemic may well be called intensive.

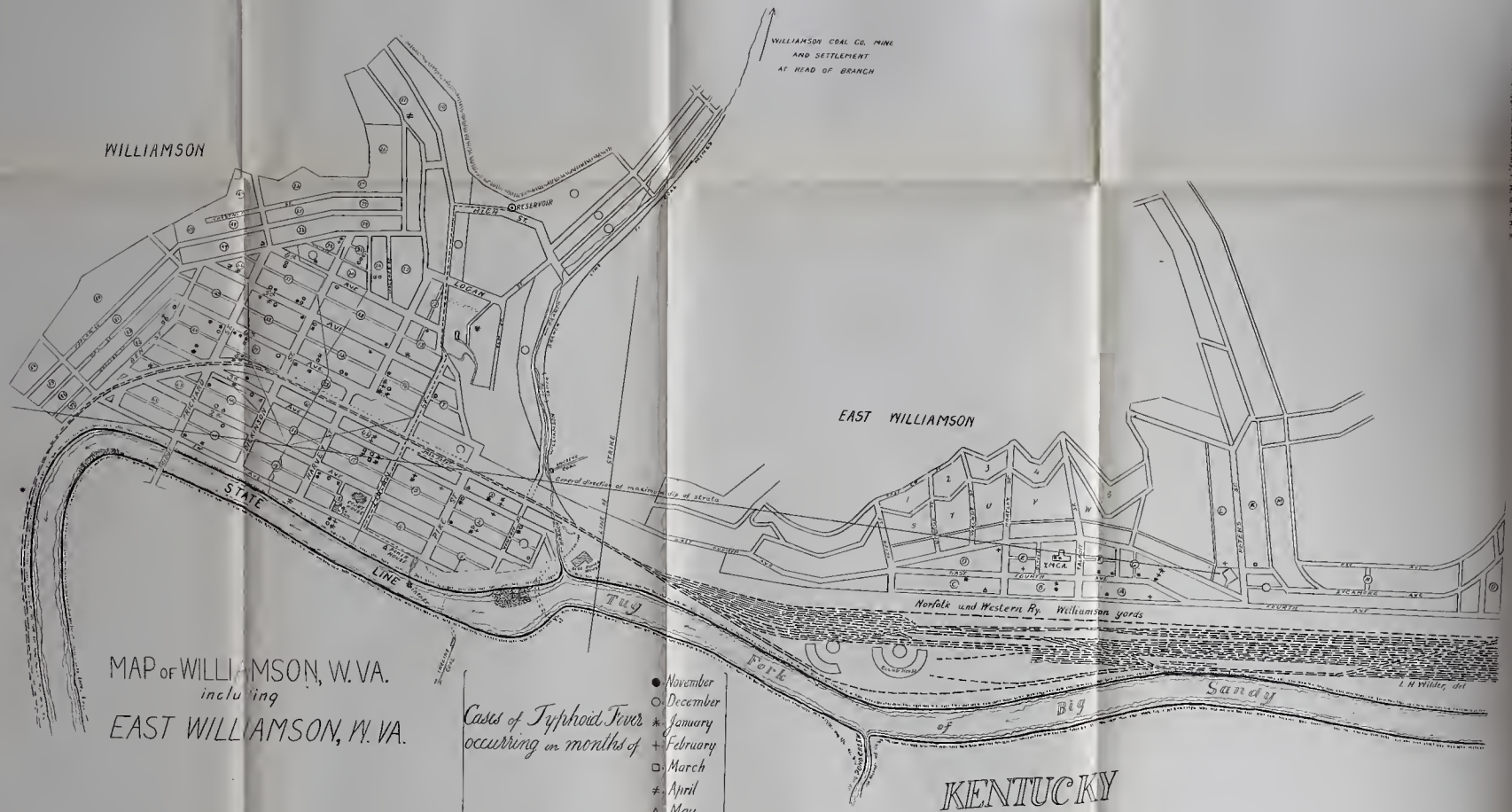
Although the mortality was low, the eleven deaths among a population of 5,000 constitute a death rate of 220 per 100,000 for a period of only seven months. This is just double the highest death rate from typhoid fever in any registration city of over 100,000 population, included in the Census Report of Mortality Statistics for 1908 (Columbus, Ohio, 110.5 per 100,000), and was equaled in 1908 in only two of the smaller towns included in this report, Mankato, Minn., 276 per 100,000, and Sharon, Pa., 244 per 100,000.[a]

The 152 cases of typhoid fever in Williamson, had their onset by months as nearly as could be ascertained, as follows:

TABLE NO. 8.—*Onset of cases and onset of fatal cases by months, from November, 1909, to May, 1910, inclusive.*

Date.	Total cases.	Cases terminating fatally.
1909.		
November	20	.....
December	23	4
1910.		
January	53	2
February	21	2
March	14	1
April	12	2
May	9	.....
Total	152	11

[a] Ninth Annual report, Bureau of the Census, Washington, 1910, Mortality Statistics, 1908 (p. 36).



MAP OF WILLIAMSON, W. VA.
including
EAST WILLIAMSON, W. VA.

Typhoid Fever
in months of

The epidemic began quite explosively in November, reached its acme in January, and from that time declined quite steadily. It can hardly be said, however, that the epidemic had altogether subsided at the time of investigation, for the incidence of nine cases in the month of May corresponds to an annual incidence of 108 (2,160 per 100,000), a very excessive, if not epidemic rate. The fatal cases in the above summary are tabulated according to date of onset. It is rather striking that none of the cases having onset in November terminated fatally, and only two (3.8 per cent) of the 53 cases occurring in January were fatal, while of the cases having onset in December, a high percentage (17.4 per cent) were fatal.

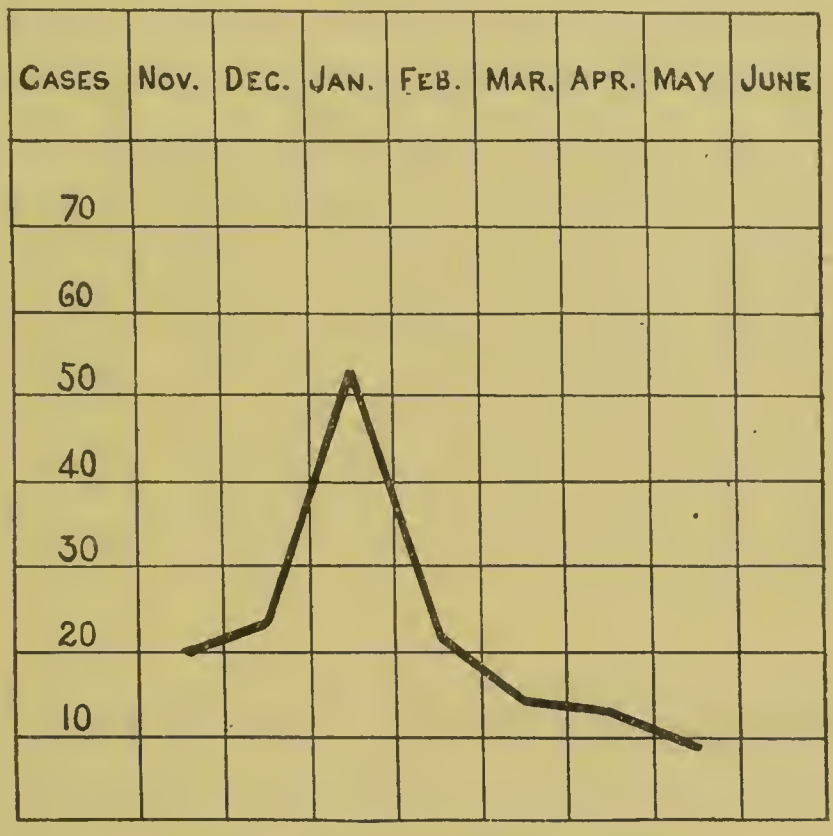


CHART NO. 1.—Showing onset of cases by months.

As many cases as possible were located and platted on a map of the town. Very considerable difficulty was experienced in the location of cases. The town has not yet reached the stage at which street numbers are in use for locating houses, yet it is already of such size that even those residents with the most extensive local knowledge are unable to locate all the residences. The difficulty was greatly increased by the large transient population. Of the 152 reported cases, 38 were known to have moved away from Williamson, and at least 18 others had changed their residence in the town since their illness. Eleven cases could not be located at all, and were therefore necessarily omitted from the map. Nine more cases, occurring on the upper portion of Williamson Branch can not be shown on the map, as this settlement is above the limits of the map.

The 141 located cases were distributed in the three sections of the town, Williamson proper, East Williamson, and Williamson Branch as follows:

	Estimated population.	Number of cases.	Number of people to each case of typhoid.
Williamson proper	3,500	112	+31
Williamson Branch	500	9	+55
East Williamson	1,000	20	50

From these figures it appears that the incidence of typhoid fever was greater in Williamson proper than in other sections. It is probable, however, that a large proportion of the unlocated cases belonged in East Williamson or on Williamson Branch, as the population of these sections is more transient and less known locally than the population of Williamson proper. Taking into consideration also the roughness of the estimates of the relative populations of these sections, it can not be said that any marked regional prevalence of typhoid fever has been demonstrated. The appended map is somewhat misleading in this respect, as many of the blocks shown upon the map have very few or no residences upon them. In general, the distribution of cases seems to have been roughly proportionate to the distribution of population, with notable exceptions in several well-marked foci.

AGE.

The age was satisfactorily determined in 112 reported cases, from which the incidence at various ages has been computed.

TABLE No. 9.—*Incidence of typhoid fever in persons of various ages at Williamson, W. Va.*

	Number of cases.	Percentage of total.
Under 5 years	8	7.1
5 to 9 years, inclusive	13	11.6
10 to 14 years, inclusive	14	12.5
15 to 19 years, inclusive	13	11.6
20 to 24 years, inclusive	14	12.5
25 to 29 years, inclusive	23	20.5
30 to 34 years, inclusive	13	11.6
35 to 39 years, inclusive	9	8.0
40 to 44 years, inclusive	3	2.6
45 to 49 years, inclusive	2	1.7
Over 49 years		

The above table shows that the distribution of the epidemic among the various decades was quite usual, the maximum number of cases occurring in the third decade. The proportion of cases occurring among children (31.2 per cent) is not exceptional. It is higher than in the epidemic in Omaha, investigated by Lumsden (29 per cent), and less than the average in Washington, D. C., where milk is considered an important factor in the spread of typhoid fever.

As many cases as possible were visited personally for the purpose of obtaining epidemiological data. An effort was made to visit a fair proportion of cases in each section of the town, and at the same time a fair proportion of the cases occurring in each month, but it was impossible, on account of the inaccessibility of many cases, to follow out a definite system in selecting cases for investigation. Altogether 72 cases were visited. The number and percentage of each is shown in the following summary:

TABLE No. 10.—*Number of each month's cases investigated.*

	Total cases occurring in month.	Number of cases investigated.	Percentage of cases investigated.
November	20	11	55.0
December	23	13	56.5
January	53	22	41.5
February	21	7	33.3
March	14	6	42.0
April	12	7	58.0
May	9	6	66.6

The case card used in the investigation of these cases was identical with the one used in the investigation of the origin and prevalence of typhoid fever in the District of Columbia in 1907 and 1908,[a] and essentially the same as the one described by Lumsden elsewhere in this bulletin.

[a] Bulletin No. 35, Hygienic Laboratory, Public Health and Marine-Hospital Service, 1908, p. 13, and Bulletin No. 52, Hygienic Laboratory, Public Health and Marine-Hospital Service, p. 11.

The information so obtained is presented in summarized form in Table No. 11 following.

TABLE No. 11.—*Summary of epidemiological histories of cases of typhoid fever in Williamson.*

Date.	Number of cases investigated.	Drinking water within 30 days prior to onset.			Milk within 30 days prior to onset.		Contact within 30 days prior to onset with—	
		City.	Well.	Safe (boiled or distilled).	Used.	Suspected.	Persons in febrile stage of typhoid.	Persons or excreta of persons who had had typhoid fever within 1 month.
1909.								
November	11	11	4	.....	8	.....	.....	3
December	13	12	2	1	10	.....	4	.....
1910.								
January	22	20	4	2	16	3	9	2
February	7	6	2	1	6	.....	2	.....
March	6	5	2	.....	6	1	3	1
April	7	3	2	2	1	1	1	3
May	6	4	.....	2	3	1	2	1
Total	72	61	16	8	50	6	21	10

Date.	Sanitary condition of premises.				Sewage disposal.			Disinfection of excreta.			
	Good.	Fair.	Bad.	Unknown.	Water closet.	Privy.	Unknown.	Probably efficient.	Inefficient.	None.	Unknown.
1909.											
November	2	3	3	3	8	3	.....	.....	3	5	3
December	2	5	4	1	10	3	.....	2	4	4	3
1910.											
January	4	7	10	1	14	8	.....	2	7	8	5
February	1	1	5	.....	1	6	.....	.....	3	3	1
March	2	1	3	.....	4	1	1	3	1	1	1
April	3	.....	4	.....	6	1	.....	.....	2	2	3
May	2	.....	4	.....	4	2	.....	2	3	1	.....
Total	16	17	33	5	47	24	1	9	23	24	16

A consideration of the data obtained from the 72 cases investigated, together with other data presented, warrants some conclusion as to the probable origin of the typhoid fever in Williamson.

The sources of infection to be considered are:

(1) Foodstuffs, especially milk.

(2) Water.

(3) Contact with cases of typhoid fever, either direct personal contact or less direct contact with their excreta, through the agency of flies, dust, leaky sewers, etc.

DISCUSSION OF EPIDEMIOLOGY.

IMPORTED CASES.

Of the 72 cases investigated, four, railroad employees, had been absent from Williamson almost daily within thirty days prior to onset of illness.

Three other cases had been absent for periods of one to ten days during the thirty days prior to onset. Two cases developed between fifteen and thirty days after coming to Williamson. In none of the foregoing cases was there any known exposure to infection outside of Williamson, while in several exposure in Williamson was definitely shown. There is no strong probability of any of these cases having been contracted outside of Williamson. On the other hand information was obtained from various sources of persons who undoubtedly contracted typhoid fever in Williamson but developed it elsewhere. A few of such cases, whose residence and history in Williamson were known, have been included among the Williamson cases, but most of them have not been so included. On the whole, no deduction need be made for cases imported into Williamson, their number being in all probability more than balanced by the number of exported cases.

MILK.

The only milk supply common to more than one or two score of people in Williamson comes from Portsmouth, Ohio, and is said to be pasteurized. This milk is used at the Norfolk and Western Y. M. C. A., where meals are served to about 150 people daily. A limited number of families also purchase this milk for home use. Nothing was found in the course of the investigation to cast suspicion upon this milk supply as a source of infection.

Many of the families in Williamson keep one or two cows, for home supply, and usually sell small quantities of milk to neighbors. Peddlers bringing milk from the nearby country sell small quantities to various families. Those who buy milk, however, either from neighbors or peddlers usually do so very irregularly, often having no regular source of supply and getting their milk from perhaps half a dozen different sources in the course of a month. Under such circumstances the rôle of milk in the spread of typhoid fever is very difficult to trace. Since scarcely any source of milk supply is common to more than half a dozen families, usually living close together, milk can readily be excluded as the cause of a sudden outbreak of 20 widely scattered cases, such as occurred in November, the first month of the epidemic. In 50 of the 72 cases investigated, milk had been used either as a beverage, on cereals, or in coffee within thirty days prior to the onset of illness. In fifteen of these cases the milk was

obtained from cows owned by the patient's family. In 6 of the cases investigated the milk used within thirty days prior to onset of illness had come from premises on which a case of typhoid fever was under treatment at that time, and must therefore be reckoned as a possible source of infection. In three of these cases milk is considered the most probable source of infection, no other probable source being discovered.

No license is required for the sale of milk in Williamson, and there is no sanitary supervision over this traffic. Considering the facts that milk is often sold from premises on which a case of typhoid fever is being nursed, that it is not infrequently handled by the nurse, with little or no precautions, and that the attendant dangers are seldom realized by either vendor or purchaser, it must be admitted that raw milk is in general a dangerous foodstuff under present conditions in Williamson, and it may be suspected that it plays a considerable part in maintaining the endemic prevalence of typhoid fever there.

ICE CREAM.

The ice cream sold in Williamson is mostly obtained from Portsmouth, Ohio, said to be made of pasteurized milk. From cases of typhoid fever occurring in the fall and winter months, no reliable histories could be obtained as to their consumption of ice cream prior to illness. The majority of patients thought it improbable that they had taken ice cream within a month prior to illness and were quite certain that within that time they had not taken any which came from the drug stores—the only source of supply common to many people.

OTHER UNCOOKED FOODS.

It appears that raw shellfish are very little used in Williamson, and they can be definitely excluded as an important source of infection. No satisfactory information could be obtained as to the use of raw fruits and vegetables. During the fall and winter months, when the epidemic was at its height, very few raw vegetables were being eaten. The ultimate sources of the raw fruits and vegetables were so various that simultaneous infection of all these sources is highly improbable; such foodstuffs may therefore be excluded as important factors in the causation of the epidemic.

WATER.

The water supply of Williamson, with its known pollution, which has already been discussed, suggests itself at once as a most probable cause of the epidemic of typhoid fever.

It was found that 61 out of the 72 investigated cases (81.3 per cent) had used raw city water for drinking more or less constantly within thirty days prior to their illness.

Considering separately the investigated cases occurring in various months, it was found that of the cases occurring in—

	Per cent.
1909.	
November	100
December	92.6
1910.	
January	90.9
February	85.6
March	83.3
April	42.7
May	66.6

had used city water for drinking more or less constantly within thirty days prior to onset of symptoms.

Eight patients (11 per cent) had used only boiled or distilled water for drinking. Sixteen had used water from various wells, mostly shallow; but thirteen of these had also occasionally drunk city water, and are therefore included among the number given as having used city water.

For the cases occurring in the month of November, the drinking water is the only probable source of infection which could be shown to have been common to all cases; and the sudden outbreak of twenty cases scattered widely over the town strongly indicates the operation of some widespread, common cause.

The late summer and fall of 1909 were unusually dry and the volume of Tug River is said to have been smaller than it had been in many years. The precipitation in inches at Williamson, from August 1, to December 31, for the years 1901–1909, as given by the Weather Bureau, is shown in the following table, compiled from a publication of that bureau [a] and from additional data furnished for the period from July 1, 1909, to July 1, 1910.

TABLE No. 12.—*Total precipitation from August 1 to December 31 for the years 1901–1909.*

Year.	Precipitation.	Year.	Precipitation.
1901	22.98	1906	21.88
1902	15.52	1907	16.10
1903	8.57	1908	12.16
1904	17.06	1909	8.80
1905	16.40		

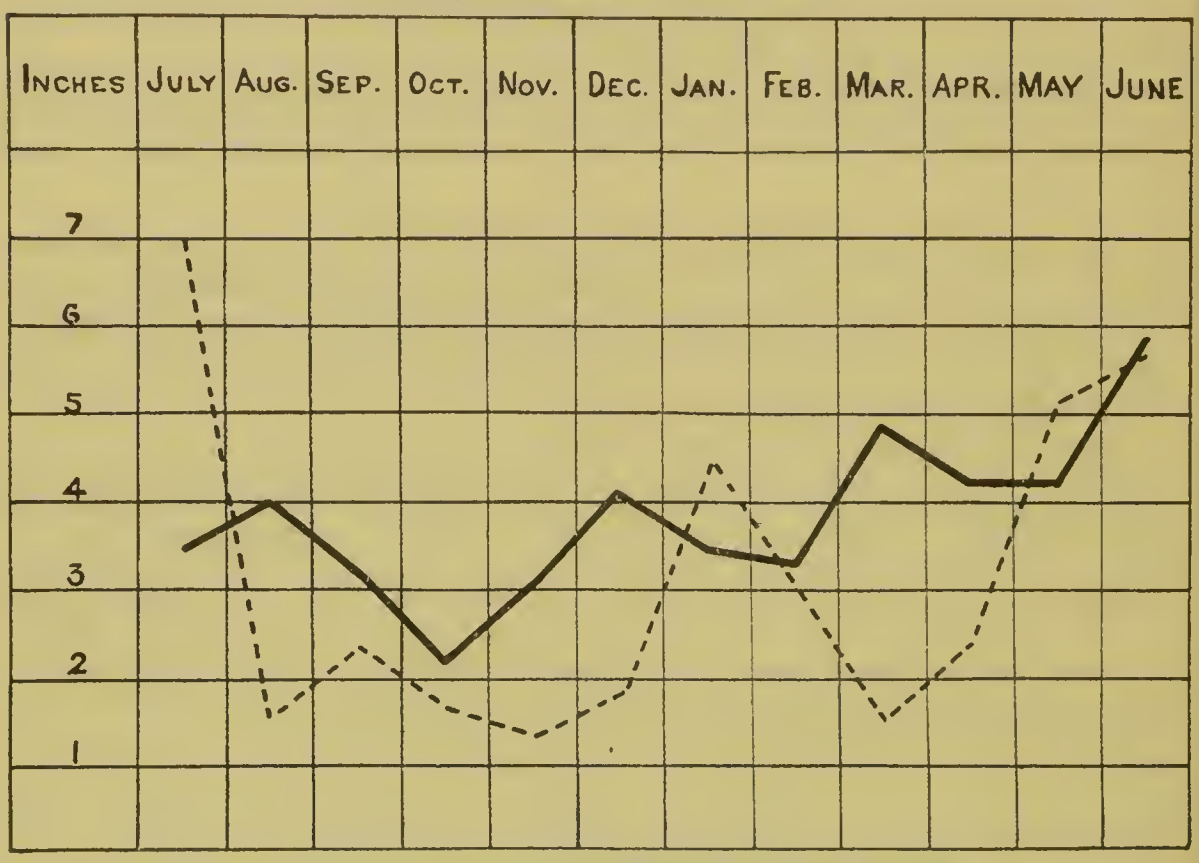
From this table it is seen that the rainfall for these months was less in 1909 than it has been in any year since 1903, and far below the average.

[a] Summary of the Climatological Data for the United States by Sections, Section No. 74, Southern West Virginia and Southwestern Virginia, U. S. Department of Agriculture, Weather Bureau

Chart No. 2, constructed from data from the same source, shows the monthly precipitation from July 1, 1909, to June 1, 1910, compared with the mean monthly precipitation from 1901 to 1908, inclusive.

Under these weather conditions it may be inferred that the amount of sewage pollution entering Tug River was less than usual, as probably a large proportion of the pollution of this river comes from surface washings, carried in by heavy rains, but on the other hand the dilution of such sewage as continued to be discharged into the river was certainly much less than usual. Whether or not the result was

CHART No. 2.—Showing monthly precipitation from July, 1909, to June, 1910, as compared with mean monthly precipitation for previous years.



———— = Mean monthly precipitation in inches, 1901–1908, inclusive.
- - - - - - - - - - - - = Monthly precipitation, in inches, July, 1909, to June, 1910, inclusive.

a greater degree of pollution than usual can not be definitely stated in the absence of any bacteriological examinations made at that time.

It is certain that from the two nearest, and therefore most dangerous, sources of considerable pollution the amount of sewage discharged into the river during this period of excessively low water was not diminished in proportion to the diminution of the river's volume. Matewan, a town of about 1,000 population, 9 miles above Williamson, has a closed sewerage system. This sewage would therefore continue to be discharged into the river independently of rainfall. The other important nearby source of pollution is Williamson Branch. It has already been shown that this little stream, carrying the sewage

of some 500 people, empties into Tug River only a few hundred yards above the intake for the Williamson water supply, and that the direction of flow is such that the water of this branch passes over the intake before becoming thoroughly mixed with the water of the river. During the dry season, the volume of Williamson Branch was kept up to some extent by the water used in washing coal at the Williamson Coal Company's mine, the water used for this purpose being obtained partly from a deep well and partly from the municipal supply. Tug River being greatly diminished in volume, and Williamson Branch, while also diminished, being proportionately less so than the river, it is obvious that at the intake there would be a larger proportion than usual of water from Williamson Branch, which is much more highly polluted than is Tug River.

The exact sources of typhoid infection entering Tug River at this time can not be given. It is known that during October there was at least one case of typhoid fever in the settlement at the head of Williamson Branch, and there is good reason to believe that a part of the excreta from this patient must necessarily have found its way into the stream without adequate disinfection. Typhoid fever was present also at Matewan, 9 miles above Williamson, and undoubtedly at various other points along the river

Evidence strongly suggesting that infection of Tug River water was the primary cause of this epidemic is furnished by the history of the epidemic in the settlement of mine employees at the head of Williamson Branch. This settlement was supplied with drinking water from the company's deep well until some time in December, 1909, when the well failed and city water had to be used for drinking. With the exception of one case in October, no typhoid fever is known to have occurred in this settlement during the fall and early winter of 1909. In January, within two to six weeks after the use of Williamson water was begun, seven cases developed among the 150 people in this settlement

Additional evidence is furnished by the experience of the two settlements nearest to Williamson.

Chattaroy is the town next below Williamson on Tug River. It is about 3 miles below Williamson, at the mouth of Buffalo Creek. Extending up the creek some 2 miles from Chattaroy are settlements of employees of several coal mines located there. The aggregate population of these settlements and the village of Chattaroy is about 1,000 to 1,500. All these people get their water supply from pipe-lined, driven wells, averaging about 100 feet in depth. Doctor Price, who has the practice of these mines, stated that there had been but one case of typhoid fever among these people since July, 1909, and that this patient had visited Williamson frequently within a month

prior to illness. At Borderland and Hatfield, mining settlements near Chattaroy, likewise supplied with deep-well water, there were no cases of typhoid fever during the winter. At Goodman, a settlement of about 150 persons on the bank of Tug River just above the mouth of Buffalo Creek, there had been four cases of typhoid fever during the winter of 1909–10. Doctor Price stated that two of these cases were imported from Williamson, and the other two had used the river water for washing and perhaps for drinking. Altogether, in the settlements of Chattaroy, Borderland, Hatfield, and Goodman, with an aggregate population of 1,500 to 2,000, there were but 5 cases of typhoid fever during the seven months in which there were 152 cases in Williamson, and 3 of these 5 cases are suspected to have been imported from Williamson. The population in these settlements is somewhat less dense than in Williamson, and sanitary conditions generally better. The difference in this respect is, however, apparently not sufficient to account for the great difference in the typhoid rate.

About 9 miles above Williamson, on Tug River, at the mouth of Mate Creek, is Matewan, a town of about 1,000 population. The public water supply here is obtained from Tug River, below the town's sewer outlet and without purification. I was verbally informed by Doctor Turner of Matewan that there had been 30 to 35 cases of typhoid fever in Matewan during the past winter—more in January than in any other month. At Redjacket, a mining settlement of possibly 900 people, a few miles above Matewan, on Mate Creek, there had been about 30 cases of typhoid fever during the winter. Deep wells supply water to this camp, but Doctor Turner was of the opinion that on account of the mineral impregnations of the deep-well water many people preferred to drink water from the near-by creek. The incidence of typhoid fever in Matewan and Redjacket, 60 to 65 cases among 2,000 population, is so near that in Williamson as to strongly indicate the operation of a common cause, most probably water.

If infection of the water of Tug River was the cause of the unusual prevalence of typhoid fever in Williamson, there must have been some unusual condition of the water operative during the fall and winter of 1909–10 to increase the infectiousness of this water, since water from the same source had been used for several years without causing such very excessive prevalence of typhoid fever.

Information as to the prevalence of typhoid fever on the Tug River watershed during the months immediately preceeding November, 1909, is wanting. There is, however, no evidence of very unusual prevalence during these months; consequently no reason to suppose that an unusual number of typhoid germs found their way into the river at that time. The only unusual condition ascertained is the extremely small volume of the river during this period, result-

ing, presumably, in unusual concentration of its sewage pollution. It is rather striking that the epidemic should have commenced to subside in February, when in all probability the amount of typhoid excreta emptied into the river immediately above Williamson was greater in January and February than in any other months of the year. The possibility of the existence of other conditions affecting the virulence or viability of typhoid bacilli in water suggests itself. What constitutes such conditions, however, is not known. Some light may perhaps be thrown upon this point by a careful comparison of the climatological conditions existing at various places during and prior to water-borne epidemics of typhoid fever and by careful studies of the biology of surface waters under varying climatological conditions.

CONTACT.

The 141 located cases of typhoid fever occurred in 99 houses. In 64 of these houses there was but 1 case in each house. In 32 houses there were two or more cases, and in 3 more houses, one case, with one or more suspected cases. Altogether, then, in approximately one-third of the houses affected there was more than one case. A study of the accompanying map will show that in the majority of instances where two or more cases occurred in a house, the interval between cases was such as to make contact infection of the later case from the earlier seem very probable.

The houses having more than one case apiece may be tabulated as follows:

Houses with—	Number.	Cases.
2 cases	23	46
1 case and 1 suspected case	2	2
3 cases	6	18
2 cases and 1 suspected case	1	2
1 case and 2 suspected cases	1	1
4 cases	1	4
4 cases and 1 suspected case	1	4
Total	35	77

In the 35 houses where there was more than one case in each house the total number of cases was 77—approximately one-half of

all reported cases. These figures are in striking contrast to the corresponding figures for the District of Columbia in 1906,[a] 1907,[b] and 1908.[c]

	Total number of cases investigated.	Number of cases occurring in houses where there was more than one case in a house.	Percentage of cases occurring in houses where there was more than one case in a house.
District of Columbia:			
1906	747	103	13.9
1907	523	73	13.9
1908	542	81	14.9
Williamson, 1909–10	141	77	54.6

These facts alone, derived simply from a study of the dates and locations of cases, would indicate that a high percentage of the cases were probably due to contact with previous cases, an assumption which is supported by the results of the investigation of individual cases.

It was found that 21 (29.4 per cent) of the 72 cases investigated gave definite histories of contact usually constant and intimate within the thirty days prior to the onset of their illness with previous cases of typhoid fever in the febrile stage.

Ten more cases gave histories of contact with persons who had recovered from typhoid fever less than one month previously, or of presumable contact with the excreta of such persons. For instance, in two cases, the patient had developed the disease within a month after moving into a house just vacated by a typhoid convalescent. Other cases included under this head are those occurring in houses less than 200 yards distant from privies into which the undisinfected excreta of typhoid-fever patients had been emptied within a month prior and when the direction of drainage or the prevalence of flies was such as to make conveyance of infection easily possible. Altogether 37 cases (51 per cent) gave a history of contact with persons who had had typhoid fever within six months prior.

The contacts determined among the 72 investigated cases, tabulated by months, are as follows:

[a] Report on the origin and prevalence of typhoid fever in the District of Columbia, by M. J. Rosenau, L. L. Lumsden, and Joseph H. Kastle (including articles contributed by Ch. Wardell Stiles, Joseph Goldberger, and A. M. Stimson). Hygienic Laboratory Bulletin No. 35.

[b] Report No. 2 on the origin and prevalence of typhoid fever in the District of Columbia, 1907, by M. J. Rosenau, L. L. Lumsden, and Joseph H. Kastle, Hygienic Laboratory Bulletin No. 44.

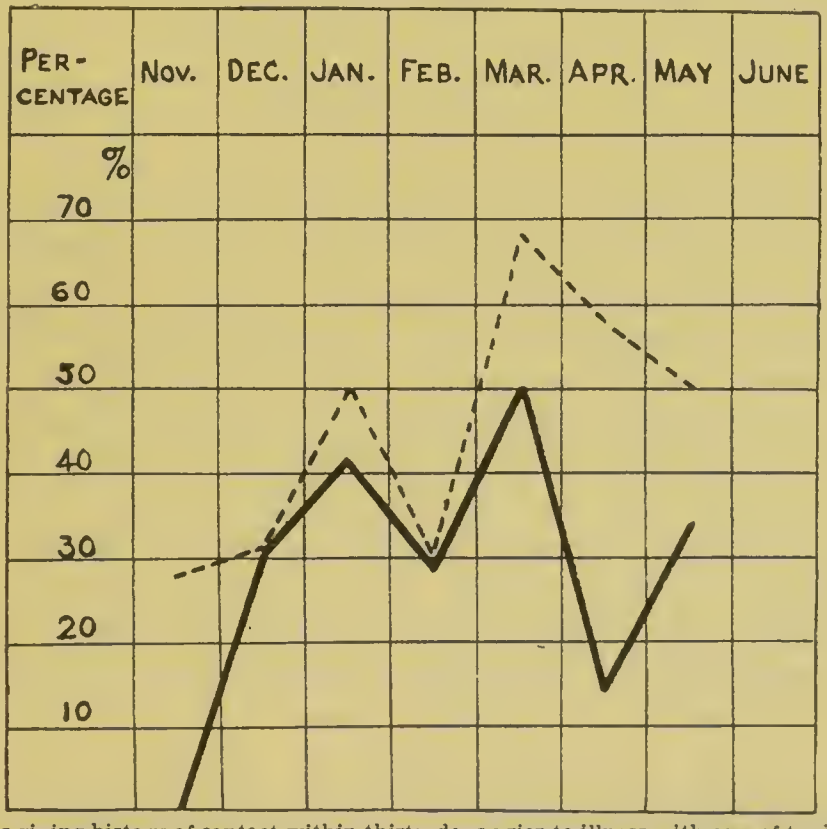
[c] Report No. 3 on the origin and prevalence of typhoid fever in the District of Columbia, by M. J. Rosenau, L. L. Lumsden, and Joseph H. Kastle, Hygienic Laboratory Bulletin No. 52.

TABLE NO. 13.

Date.	Number of cases investigated.	Cases giving history of contact within thirty days prior to onset, with—			
		Persons in febrile stage of typhoid fever.		Persons who had had typhoid fever within 1 month or the excreta of such persons.	
		Number.	Per cent.	Number.	Per cent.
1909.					
November	11			3	27.0
December	13	4	30.7		
1910.					
January	22	9	40.9	2	9.0
February	7	2	28.5		
March	6	3	50.0	1	16.6
April	7	1	14.2	3	42.8
May	6	2	33.3	1	16.6
Total	72	21	30.0	10	14.0

Especially noteworthy in this table is the absence of traceable contacts to account for the cases occurring in November, contrasted with the increasing percentage of cases in subsequent months giving a history of contact. Chart No. 3 shows graphically the percentage of contacts traceable in different months.

CHART NO. 3.—Showing percentage of cases in various months, giving history of contact with previous cases of typhoid fever.



———=Cases giving history of contact within thirty days prior to illness with case of typhoid in febrile stage.

------=The above, plus cases giving history of contact with persons or the excreta of persons convalescent from typhoid less than one month.

In drawing inferences from these facts it is necessary to consider: (1) That it is more difficult to trace contacts when histories are taken several months subsequent to recovery; (2) that during the months of November, December, January, and February there were progressively more cases of typhoid fever under treatment in Williamson, and consequently more chances for well persons to come into contact with such cases; (3) that nearly 3 per cent of the total population of Williamson had typhoid fever at some period between November, 1909, and June, 1910, and that considerably more than this percentage must therefore necessarily have been thrown into contact with febrile cases of typhoid fever.

There can, however, hardly have been more than 75 cases under treatment in any one month. Allowing an average of ten contacts for each case, there would be 750 out of 5,000 people (15 per cent) who would give a history of contact with cases of typhoid fever within that month. There were an average of 22 cases under treatment each month and on the above basis of calculation 220 contacts. It is probable, too, that five contacts for each case of typhoid fever in the febrile stage is a more nearly accurate estimate than ten (4.4 per cent of the total population) each month. As compared, then, with this percentage of the total population who may be presumed to have been in contact with cases of typhoid fever within one month the high percentage of cases of typhoid fever (30 per cent) giving such a history clearly indicates that contact played a very considerable causative part in the prevalence of the disease.

BACILLUS CARRIERS.

In two instances where the epidemiological evidence strongly suggested a bacillus carrier as the source of infection in a household, the stools and urine of the suspected persons were examined a single time with negative results. In another instance the simultaneous infection of two members of one household seemed most probably due to a recent convalescent who aided in preparing and serving the food, but no examination of stools or urine could be made in this case. In a community where typhoid fever has been so constantly endemic as in Williamson it may be accepted as reasonably sure that there are a certain number of permanent bacillus carriers, and that the number of both permanent and temporary carriers must have been considerably augmented by the recent epidemic. The rôle of bacillus carriers in the causation of typhoid fever is, however, more difficult to trace in a community where there are numerous other probable sources of infection than in a community where typhoid fever is rare and other sources of infection more readily excluded.

FLIES.

Where open privies are so numerous as in Williamson there is every reason to suspect that flies play a considerable part in the spread of typhoid fever in summer, and in three of the investigated cases occurring in April and May flies were considered the most probable carriers of infection, all of these cases being within 100 yards of the same open privy, which, during March and April, had received the undisinfected excreta of two typhoid fever patients.

It is to be borne in mind that in the later months of the epidemic there were very numerous foci of infection, and correspondingly numerous avenues of contact, many of them unrecognizable, especially the fairly constant percentage of permanent bacillus carriers, the larger percentage of convalescent temporary carriers, and probably unrecognized ambulant cases. Especially in the warmer months, with increased prevalence of flies and other insects and increased consumption of uncooked foods, the avenues of infection must obviously have been multiplied and must at the same time have become more difficult to trace. In view of these facts, while water can not be excluded as a continued cause of the prevalence of typhoid fever in the later winter and spring months, contact alone, under existing conditions of sewage disposal and other prophylaxis in Williamson, might easily explain the continued prevalence of typhoid fever.

SANITARY CONDITION OF PREMISES ON WHICH TYPHOID FEVER OCCURRED.

The sanitary condition of the premises on which the 72 investigated cases of typhoid fever occurred was found to be good in 17 cases, fair in 17, bad in 33, these terms being used chiefly with regard to sewage disposal, general cleanliness, and such other conditions as would have a bearing upon the spread of typhoid fever.

The percentage of cases occurring under bad sanitary conditions is, so far as can be judged by the results of a sanitary survey of a part of the town, disproportionately high. The sanitary conditions of 21 premises, on each of which more than one case of typhoid fever occurred, is known. The conditions were bad on 14 of these premises (67 per cent), with an aggregate of 33 cases; fair on 3 (14 per cent), with an aggregate of 6 cases; good on 4 (19 per cent). This disproportionately high percentage of insanitary conditions in premises where typhoid fever was unusually prevalent indicates very clearly the effect of such conditions with the attendant poverty, ignorance, and neglect of prophylactic measures in maintaining a focus of typhoid fever.

PROPHYLAXIS.

In the investigation of cases the prophylactic precautions exercised in nursing the case were ascertained whenever possible. This information was satisfactorily obtained with regard to 56 cases. The

measures used in disinfection of the excreta were probably efficient in 9 cases (16 per cent), certainly inefficient in 23 (41 per cent), while in the remaining 24 (43 per cent) no disinfection had been attempted. Altogether, then, in 84 per cent of the cases investigated disinfection of excreta was, according to the statements of the nurse, either not attempted or was carried out in such a way as to be certainly inefficient. Prophylactic measures other than disinfection of excreta were found to have been even more neglected.

This is probably the most significant fact brought out in the investigation. Taken in connection with the faulty methods of sewage disposal it fully explains the succession of cases in the same house and the large number of other contact infections. And if from the practice at Williamson any inference can be drawn as to other towns farther up the river, the probable degree of typhoid infection of the water of Tug River becomes appalling.

SUMMARY.

Typhoid fever became unusually prevalent in Williamson in November, 1909, from which time until January, 1910, the number of cases increased monthly. From January to June, 1910, the number of cases decreased monthly, but the rate of prevalence remained excessive. Evidence derived from a study of the epidemic indicates that this unusual outbreak was due to infection of the municipal water supply obtained from Tug River; and it seems highly probable that unusual weather conditions, resulting in extremely low water in the river were important contributory causes. The heavy rainfall in January was followed by a sharp decline in the number of cases occurring in the next month, notwithstanding that during January the total amount of typhoid excreta washed into the river at Williamson was certainly greater than in previous months. The same may be assumed as true of Matewan, just above Williamson, and probably of many other towns on the river. The decline in the epidemic indicates a decrease in the amount or virulence of infection in the water during January. Whether this can be explained altogether by dilution, due to increased volume of the river, is not determined.

Infection by direct contact with cases of typhoid fever was undoubtedly responsible for a large proportion of the cases occurring subsequent to November, 1909. There is good reason for supposing that infection by direct contact and less direct contact, as through flies and through uncooked foods, has been the chief factor in maintaining the prevalence of typhoid fever since January. While water can not be excluded as a factor in the causation of typhoid fever since January, there is no direct evidence that it has been a factor since then; and there are enough other probable sources of infection to reasonably account for the continued prevalence of typhoid fever in Williamson.

PREVALENCE OF DIARRHEAL DISEASES.

A severe choleraic diarrhea, affecting persons of all ages, is, according to the statements of local physicians and other residents, unusually prevalent in Williamson. The infant mortality rate could not be ascertained, and it is therefore not known whether this is in excess of the average death rate for other localities. No fatal cases of diarrhea in adults were reported, but the local physicians gave accounts of many cases so severe as to be alarming. In the more severe cases of diarrhea the temperature is subnormal, there are general muscular cramps, extreme prostration, and rapid emaciation, with profuse and frequent watery stools, seldom if ever containing blood. In the more common, less severe cases the only symptoms are diarrhea, weakness, and sometimes nausea. Elevation of temperature is unusual and never great. The economic effect of such a common and disabling malady is obviously very considerable.

This diarrhea is generally believed to be due to drinking the river water. A number of observations tend to confirm this view. In the investigations of cases of typhoid fever I was told quite often that a whole family, on first coming to Williamson and drinking river water, had been affected within a week by severe diarrhea, which ceased when the use of raw river water was discontinued. During the period of increased prevalence of typhoid fever in the winter of 1909–10 severe diarrhea was also unusually prevalent. The superintendent of machinery and repairs of the Norfolk and Western Railway Company's yard stated that since the installation in the yards of a distilling plant to supply drinking water to the employees there had been a very considerable increase in efficiency of the employees, due to decrease in the number of cases of diarrhea.

A stool from an acute case of diarrhea was examined by plating out on Endo's medium. The plates showed clear colonies resembling the typhoid or paratyphoid bacilli, almost as numerous as the red colon colonies. Several of the clear colonies were identified and found to be culturally identical with *B. paratyphosus, B*, *B. enteritidis Gärtner*, and others of the so-called "Enteritidis" group of bacilli. The organism was not agglutinated by specific typhoid agglutinating serum, paratyphoid – B serum, or paratyphoid – A serum.

Unfortunately no other case of acute diarrhea could be studied. A stool from a case of chronic diarrhea, plated out on Endo's medium, gave only typical colon-bacillus colonies. From the single case examined no conclusion is justified as to the relation of the organism isolated to the etiology of the local diarrhea. A causative relation is strongly suggested, however, by the abundance of this organism in the stool examined, the rarity of such organisms in normal stools, and the known relation of many bacilli of the Enteritidis group to acute enteritis.

MEASURES RECOMMENDED FOR THE PREVENTION OF TYPHOID FEVER IN WILLIAMSON.

The measures recommended for the prevention of typhoid fever in Williamson include:

(1) Improvement of the public water supply.

(2) Improved methods of sewage disposal.

(3) More careful disinfection and other prophylactic precautions in the care of typhoid fever patients.

(4) Supervision by the board of health over the sale of milk and the management of places where food is served to the public.

WATER SUPPLY.

It is of prime importance to obtain a water supply that will be free from sewage contamination. The supply must also be abundant, suitable for laundry and other domestic purposes, of good appearance, and palatable; otherwise its use will be supplemented by the use of unsafe water from shallow wells and springs, and the full sanitary benefits of a pure water supply will not be realized.

The ideal source of water supply, from a sanitary standpoint, is a deep well, and the practicability of obtaining a sufficient and satisfactory supply from such a source should be carefully considered by competent experts. The very slight dip of the strata in this section of the country, and the frequent occurrence of strata strongly impregnated with iron, sodium chloride, and other objectionable salts render the practicability of deep wells as a satisfactory source of water supply very doubtful.

There are said to be no mountain springs available for water supply. Small streams, draining practically uninhabited areas, are quite common in the vicinity of Williamson, but these streams are all said to fail in dry seasons and could not be used as a constant source of water supply without the construction of large and expensive impounding reservoirs. It would also be necessary to protect the catchment area from future pollution, and this would possibly necessitate the purchase of valuable coal lands.

In the event that Tug River proves the only available source of water supply, purification processes of the very highest efficiency will be necessary to render its water safe according to modern bacteriological standards, and unless measures are taken to prevent further pollution of this stream, a wide margin must be left for the inevitable future increase in its pollution.

It is quite obvious that the intake should be moved to a point above the town to escape local sewage pollution. Bacteriological and physical examinations indicate that the pollution both with sewage and with coal washings is very considerably greater at the present intake than at a point above the town.

Some process of filtration will be necessary to clarify the water and to remove as many as possible of the bacteria. The present rough intake filter is altogether inadequate, as is also the infiltration gallery of the Norfolk and Western Railway Company.

All things considered, the mechanical (American) system seems best adapted for the filtration of this water. The amount and kind of coagulant necessary will have to be determined by experience. Preliminary sedimentation before filtration would certainly improve the sanitary quality of the effluent, but it is believed that this point can be left to be settled on the basis of economy.

Any filtration system which is installed should be supplemented by a sterilization process, on account of the high degree of dangerous pollution of Tug River. The examinations of Tug River water showed *B. coli* constantly present in 0.1 c. c.—that is, at the rate of 10 per c. c. or 100 per 10 c. c. Quantative estimations of *B. coli* by Marmann's plate method showed 50 *B. coli* per c. c., which is probably not an excessive average estimate. Granting for a filtration plant a constant efficiency of 99 per cent, the effluent would still contain from 1 to 5 *B. coli* per 10 c. c., thus falling far below the standard of purity for a satisfactory filter effluent. For partial sterilization of the filter-effluent either the hypochlorite of lime or ozone may be used. Hypochlorite of lime is recommended as the more practicable because of the lesser initial cost of constructing the necessary plant and its simple and cheap application.

Pending the establishment of a safe water supply it is recommended that the people of Williamson be frequently warned by the board of health of the dangers of the present water supply, and urged to boil not only all drinking water, but also all water used for washing fruits and vegetables which are eaten raw, and for washing vessels which are used for milk.

If it is decided to adopt the hypochlorite treatment subsequent to filtration of the water, it is recommended that the plant for this purpose be installed at once, in such a location that it can subsequently be used for treatment of the filtered water, and that pending the completion of the filtration plant the water be treated with hypochlorite, as a temporary expedient.

SEWAGE DISPOSAL.

The present sewerage system should be overhauled, repaired, and extended as rapidly as possible to those sections of the town not at present provided with sewers. The use of Williamson Branch as an open sewer should be discontinued and a closed sewer laid for that section of the town. Adequate provision against flooding of the sewers should be made, either by enlarging the sewers sufficiently to

carry off the surface water following heavy rains or by diverting this water from the sanitary sewers.

All houses within a reasonable distance of a town sewer should be required to have closets connecting with the sewer. All privies on such premises should be condemned, and their contents safely disposed of. Where sewer connections are for the present impossible, all open privies should be replaced by privies of an approved sanitary model. Fly-proof can privies would be a great improvement. Dry earth or lime could be used in the cans. The care of all privies and the disposal of their contents should be under municipal control.

CARE OF TYPHOID FEVER PATIENTS.

Adequate provisions should be made for:

(1) Prompt reporting of all cases of typhoid fever.

(2) Careful instruction of the families of typhoid fever patients in the necessary prophylaxis. This should be done by a representative of the board of health.

(3) Supplying of disinfectants free of charge to the poor.

SUPERVISION OF FOOD SUPPLIES.

The sale of milk should be under some supervision by the board of health, at least to the extent of prohibiting its sale by persons living on insanitary premises or premises on which a case of typhoid fever or other infectious disease is under treatment.

The board of health should also have supervision over the public restaurants of the town. Some of these were found to be in a condition which must necessarily be a menace to the health of those who eat there.

In order that the above measures may be carried out, it is obviously necessary that the town should recognize the importance of its health department and make an adequate appropriation for the maintenance of an efficient organization.

A safe water supply may be expected with reasonable certainty to greatly reduce the prevalence of typhoid fever in Williamson, but it is to be expected with equal certainty that even with a pure water supply, if other preventive measures are neglected, the disease will remain constantly and excessively prevalent and will doubtless at times become epidemic. Compared to the cost of providing a pure water supply the cost to the town of the other measures recommended is insignificant, while their importance is, perhaps, equal to the importance of obtaining pure water.

LIST OF HYGIENIC LABORATORY BULLETINS OF THE PUBLIC HEALTH AND MARINE-HOSPITAL SERVICE.

The Hygienic Laboratory was established in New York, at the Marine Hospital on Staten Island, August, 1887. It was transferred to Washington, with quarters in the Butler Building, June 11, 1891, and a new laboratory building, located in Washington, was authorized by act of Congress March 3, 1901.

The following bulletins [Bulls. Nos. 1–7, 1900 to 1902, Hyg. Lab., U. S. Mar.-Hosp. Serv., Wash.] have been issued:

*No. 1.—Preliminary note on the viability of the *Bacillus pestis*. By M. J. Rosenau.

No. 2.—Formalin disinfection of baggage without apparatus. By M. J. Rosenau.

*No. 3.—Sulphur dioxid as a germicidal agent. By H. D. Geddings.

*No. 4.—Viability of the *Bacillus pestis*. By M. J. Rosenau.

No. 5.—An investigation of a pathogenic microbe (*B. typhi murium* Danyz) applied to the destruction of rats. By M. J. Rosenau.

*No. 6.—Disinfection against mosquitoes with formaldehyde and sulphur dioxid. By M. J. Rosenau.

No. 7.—Laboratory technique: Ring test for indol, by S. B. Grubbs and Edward Francis; Collodium sacs, by S. B. Grubbs and Edward Francis; Micro-photography with simple apparatus, by H. B. Parker.

By act of Congress approved July 1, 1902, the name of the "United States Marine-Hospital Service" was changed to the "Public Health and Marine-Hospital Service of the United States," and three new divisions were added to the Hygienic Laboratory. Since the change of name of the Service the bulletins of the Hygienic Laboratory have been continued in the same numerical order, as follows:

*No. 8.—Laboratory course in pathology and bacteriology. By M. J. Rosenau. (Revised edition, March, 1904.)

*No. 9.—Presence of tetanus in commercial gelatin. By John F. Anderson.

No. 10.—Report upon the prevalence and geographic distribution of hookworm disease (uncinariasis or anchylostomiasis) in the United States. By Ch. Wardell Stiles.

*No. 11.—An experimental investigation of *Trypanosoma lewisi*. By Edward Francis.

*No. 12.—The bacteriological impurities of vaccine virus; an experimental study. By M. J. Rosenau.

*No. 13.—A statistical study of the intestinal parasites of 500 white male patients at the United States Government Hospital for the Insane; by Philip E. Garrison, Brayton H. Ransom, and Earle C. Stevenson. A parasitic roundworm (*Agamomermis culicis* n. g., n. sp.) in American mosquitoes (*Culex sollicitans*); by Ch. Wardell Stiles. The type species of the cestode genus *Hymenolepis;* by Ch. Wardell Stiles.

No. 14.—Spotted fever (tick fever) of the Rocky Mountains; a new disease. By John F. Anderson.

No. 15.—Inefficiency of ferrous sulphate as an antiseptic and germicide. By Allan J. McLaughlin.

*No. 16.—The antiseptic and germicidal properties of glycerin. By M. J. Rosenau.

*No. 17.—Illustrated key to the trematode parasites of man. By Ch. Wardell Stiles.

*No. 18.—An account of the tapeworms of the genus *Hymenolepis* parasitic in man, including reports of several new cases of the dwarf tapeworm (*H. nana*) in the United States. By Brayton H. Ransom.

*No. 19.—A method for inoculating animals with precise amounts. By M. J. Rosenau.

*No. 20.—A zoological investigation into the cause, transmission, and source of Rocky Mountain "spotted fever." By Ch. Wardell Stiles.

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